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Volume 39, No. 6 June 1960

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Petroleum
Refiner
OIL, GAS AND PETROCHEMICAL PROCESSING

A Gulf Publishing Company Publication

A Quick Look
at This Issue

These handy digests permit checking the articles you want to read first. ☑

SPECIAL REPORT ON SEPARATION METHODS

☐ **Selective Adsorbents . . .** Some crystalline zeolites act as molecular sieves by adsorbing or rejecting molecules on the basis of their molecular size. See how these adsorbents can be used for octane improvements. Turn to **Page 125.**

☐ **Membrane Permeation . . .** From lab and economic data here, you can see how close this unit operation is to commercialization. It's a fast-breaking process so be sure you start reading on **Page 133.**

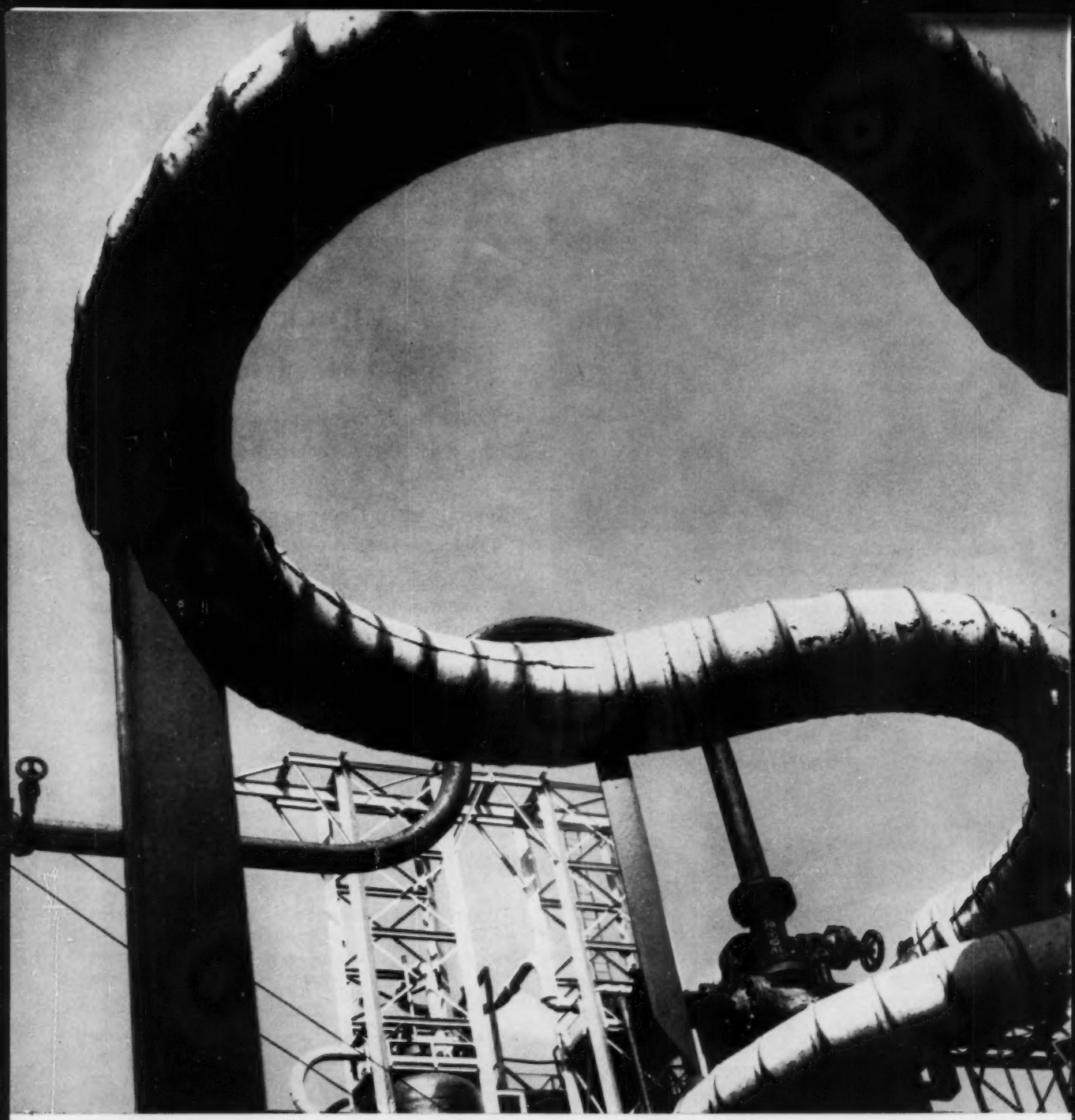
☐ **Superfractionation . . .** These columns are getting larger and longer. Here's a new design procedure that takes care of the cases where the relative volatility varies from top to bottom trays. The expert is Francis Winn and his article starts on **Page 139.**

☐ **Extractive Distillation . . .** Most of the recent developments in extractive distillation concern the choice of proper separating agent. Review these present uses of extractive distillation—a handy separating technique. Turn to **Page 146.**

☐ **Liquid Extraction . . .** After considering the volume of products requiring treatment by extractive methods, these authors forecast the future for liquid extraction. You'll also read about the application of this separation technique to: petrochemicals, naphthas, distillate fuels, catalytic feed stocks, and lubricating oils, plus a complete discussion of the equipment involved. Turn now to **Page 149.**

☐ **Thermal Diffusion . . .** The trend in thermal diffusion is toward more equipment studies rather than specific product studies. Nevertheless, this comprehensive review tells of possible application of this method in the refining and petrochemical industry. **Page 156.**

Please Turn Page →



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A Quick Look at This Issue . . .

☐ **Corrosion Measurement Short Course (Part 2) . . .** The first part of this series dealt with methods for inspecting corrosion damage which had already occurred in the plant. Now, this part covers two means of measuring the corrosivity of process plant fluids. You'll be able to review these modern techniques by turning to **Page 163.**

☐ **Unicracking Gives New Refining Step . . .** The addition of hydrocracking offers you an attractive way to convert marginal or problem cracking stocks. Therefore, you'll want to read this article which discusses the economic advantages for one of these new processes. Turn now to **Page 169.**

☐ **When Metals Poison Cracking Catalyst . . .** Here's an investigation of the effect of poisons on fluid catalytic cracking yields. You'll see how the hydrogen producing factor can be used as a criterion for operating a commercial unit and give a measure for selecting feedstocks and determining catalyst replacement rates. It all starts on **Page 177.**

☐ **Applied Hydrocarbon Thermodynamics (Part 18) . . . Fundamentals of Vapor-Liquid Equilibria . . .** If you are rusty with your understanding of the thermodynamics of equilibrium then this part is written just for you. We asked Professor Edmister to include a primer on equilibrium in this outstanding series and here it is. For your refresher, take a look at **Page 181.**

☐ **Better Test for Contaminants . . .** Here's how you can use gas chromatography to pinpoint the amount and indentity of volatile contaminants. Make your flash point determinations mean more, turn to **Page 193.**

☐ **Find Physical Properties of Methanol . . .** You'll be able to get the physical properties of liquid and gaseous methanol in a hurry after reading this article. Clip this for your notebook—turn to **Page 196.**

☐ **How Adsorption Units Are Operating . . .** After initial bugs were worked out, Texaco has found that these gas processing units operate routinely. Here's how they look on the initial problems, and what you need to consider in buying. The whole story starts on **Page 197.**

☐ **Absorber Design—Fast Yet Rigorous . . .** You can make this graphical modification to the Kremser absorption method in 2 to 3 hours. Operating data show it's accurate, too. The inexperienced absorption calculator will be able to design safely by this method. Turn now to **Page 201.**

☐ **How to Make and Use C_4 Olefins (Part 2) . . .** Presents the chemistry, production and utilization of isobutylene. It's principally used for butyl rubber, but you'll also find discussions of other important uses starting on **Page 207.**

☐ **Watch These Trends in Asphalt Specs . . .** Since older accepted tests do not predict desired engineering properties, new tests are being developed to assure good performance in actual use. For the history of old asphalt tests and new testing trends you should watch, turn to **Page 211.**

☐ **How C_6 Isomerization Works for Atlas . . .** After a year's commercial operation. a Penex C_6 isomerization unit has proven itself successful for Atlas Processing Co. A rundown on the cost data here will show what you can expect to pay for the benefits of the Penex process, so turn now to **Page 216.**

☐ **So You Want to Be a Success . . .** Before you make any more plans on just how far you want to go in your industrial career, be sure to read this article. It presents a bird's-eye view of the Executive, the Supervisor and the Engineer—and how each fits into the industrial way of life. Here's one you're going to want to clip and pass along to someone else—turn now to **Page 223.**

☐ **Organizing a Management Development Lab . . . Applied Group Dynamics: Part 2 . . .** Ordinary education or work situations rarely provide a person with the opportunity to test his social skills. But here is a method which enables you to measure how your behavior is seen by others, whether your judgments of human events fit what others see, and whether or not you understand what makes a group "go." You'll want to be sure to read this second installment of this highly interesting and informative series. **Page 227.**

☐ **Sample Bombs Can Be Bombs! . . .** Here is a case history of how and why a container filled with a sample of field butane ruptured in the laboratory of Indiana Standard's Mandan, N. D., refinery. After reading this you may want to review your own procedures and equipment for sampling light hydrocarbon mixtures, so turn to **Page 231.**

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Highest Efficiency . . . Easier to install, relamp, maintain . . .

The EV series offers exactly the right fixture for any area made hazardous by flammable atmospheres of vapors or gases, as defined under Class I of the National Electrical Code.

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Refresher of an Offer

PETROLEUM REFINER's editorial staff is in the same boat with oil, gas and petrochemical plant operators who are forever installing new units and seeking advance knowhow in an effort to improve their product. Our improvement not only embraces selection of better articles from month to month, but more skillful editing. Magazine work is something apart from processing techniques, but an engineer-writer learns the fundamentals as he wrestles with manuscripts that come to his desk. And before long he becomes a pretty good editor.

With the May issue of PR (and don't you agree that it rated high?) before us, editors underwent a refresher on points looking toward improved reader rating. Ideas that needed emphasis, it developed, checked right back to our Author's Handbook. Had its tenets been followed, critical comment would have been kept at a minimum. So each editor was told to brush up a bit on the Handbook's content because truly PR is as anxious to make its product as refined as the industry's top-flight gasoline!

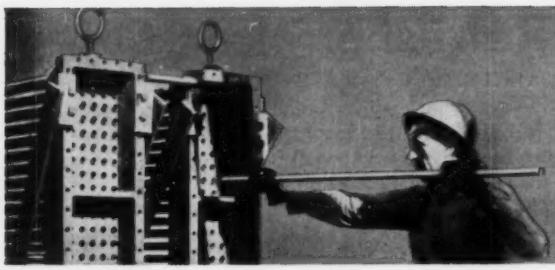
Many of our authors and certainly all engineers who want to write stand to derive hefty dividends from this same Handbook. A copy will be sent free if you will direct your request to the Editorial Director, Box 2608, Houston 1, Texas.

Wide and Good

A RECENT LETTER from a Cleveland, Ohio, process engineer contains implications that might startle an ordinary editorial staff. PR's is considerably above that rating; so we'll try to take it in stride, difficult though it may be. Lend an ear: "Because of the variety (chemistry, petrochemistry, metallurgy, refining, and petrochemical plants, including mechanical and chemical engineering design), I find PETROLEUM REFINER of more value than any other publication," he wrote. Kind words, you say, and we agree. The implication that he expects these things of us from month to month constitutes a challenge that is even more poignant than our gratitude for kind and thoughtful words. It is a wide range which interests him—and many another reader, for that matter—but our staff is geared for expert coverage of "oil, gas and petrochemical processing" and we hope to continue with a periodical that he—and thousands of others—will find eminently satisfactory.

That $$$ Flavor

THIS VERY SPACE has on prior occasions contained comment re the selfsame subject and here just before PR's Special Report on Costs scheduled for July, we would repeat: If an editor wants his readers to go into action like Bill Veeck's new White Sox scoreboard, then lay before them an authentic article relating to the well known Yankee dollar mark. That's exactly what we are doing in July when PR will present a data-packed article dealing with the effect of raw materials on manufacturing costs and another which tells how to control these manufacturing costs. Put it on your **must** list.



CONDENSER AND HEAT EXCHANGER CLINIC

Edited by David S. Hibbard, Metallurgical Engineer
The American Brass Company, Waterbury 20, Conn.

The trend is to longer, small-diameter heat exchangers in high-pressure, high-temperature systems

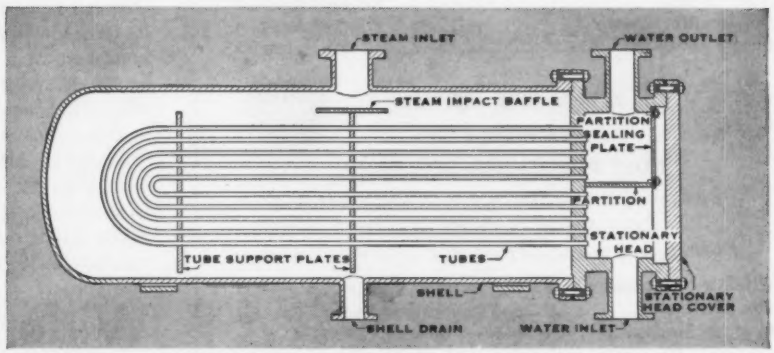
Where relatively high pressures are involved—as in power station feed-water heaters and many exchangers for oil refineries, chemical, and petro-chemical plants—it is very costly to get increased capacity by increasing shell diameters beyond about 48″.

It is more economical to lengthen the equipment. And this means longer tubes —either as straight lengths with a floating head or as U-bend tubes.

U-bend Tube Design of exchangers has several inherent advantages, particularly when wide temperature differences exist in the unit. Each U-bend tube individually takes care of its expansion stresses. The number of rolled tube joints is cut in half. The absence of a floating head eliminates one gasketed joint and reduces the total weight of the tube bundle, making handling easier.

The average length of tubes involved is already beginning to crowd the heretofore standard maximum of 60 feet. And The American Brass Company, recognizing the trend to still greater length, has installed new mill equipment to produce tubes up to 100 ft. in straight lengths—in U-bends with the length of the straight leg up to 50 feet. The radius of the bend to the center line can be as small as 1½ times the outside diameter of the tube, or as great as 30 inches.

Dual-gage Tubes. For the tubes with short-radius bends in the middle of the bundle, provision should be made for extra metal at the bend to prevent thinning of the tube wall below a safe minimum for the service. Dual-gage tubes are made with extra wall thickness in the area of the bends. This cuts cost and weight, as the extra metal is only at the bends where it is needed and not down the entire length of the tube. Cost savings have been estimated at from a few cents to several dollars a tube, depending on the alloy used. The American Brass Company makes dual-gage tubes one BWG thickness heavier in the bend area.



Schematic drawing of U-bend-tube-design feed-water heater. *Courtesy The Griscom-Russell Co.*

Annealing. Both single-gage and dual-gage tubes are annealed at the bend to relieve stresses developed in the bending process, which otherwise might lead to stress-corrosion cracking.

Testing. Tube quality is particularly critical in high-pressure, high-temperature service. Furthermore, U-bend bundles are so tightly packed that it is difficult to remove a defective tube, particularly at the center. So The American Brass Company has added equipment to make hydrostatic tests up to 6000 psi on even the longest U-bend tubes after they have been bent. Air tests up to 250 psi with tube submerged in water can be made on straight lengths up to 60 feet.

Technical Assistance. For more detailed information on extra-long tubes, U-bend, Dual-gage, or Duplex tubes to meet special problems, address: The American Brass Company, Buffalo Division, Buffalo 5, New York. In Canada: Anaconda American Brass Limited, New Toronto, Ont. 5676

Compact tube bundle for a feed-water heater using U-bend tubes averaging 45′ long. Similar units have been made with tubes up to 85′ long.

ANACONDA®
TUBES AND PLATES FOR
CONDENSERS and HEAT EXCHANGERS
Made by
THE AMERICAN BRASS COMPANY

Quick Look at Industry...

Possible Changes in Imports Plan . . .

Oil Imports Administration proposes change in mandatory imports program. Would include:

1. Reducing allocations of "historical" importers by subtracting from their present allocations, daily average of crude imported overland between Sept. 1, '58 and March 10, '59.
2. Reducing ratios of imports-to-refinery inputs in Dists. 1-4.
3. Increasing ratios of imports-to-refinery inputs in Dist. 5 (Wash., Ore., Calif., Nev., and Ariz.).

Synthetic Fiber Star is Bright . . .

Look for synthetic fibers to continue spectacular growth with nylon leading the field. Chemstrand President O'Neal predicts these figures for '65: nylon—668 million lbs.; acrylics—237 million lbs.; polyesters —190 million lbs.; others (including polyethylene and polypropylene)— 51 million lbs. Key to nylon growth is in tire cord fabric.

Possibly Petrochemicals from Pakistan . . .

West German technical mission to Pakistan says gas reserves at Sui and other areas will sustain petrochemical industry based on natural gas. Recommends building plants to make natural gasoline, acetylene, acrylonitrile PVC, methyl methylacrylate, and synthetic fibres.

Red Oil Forced on U.S. Refineries . . .

Following new Cuban-Soviet trade pact, Cuban government tells Jersey Standard, Texaco and Shell they must buy Russian crude for Cuban refineries. Quotas will probably hit 6,000-10,000 bpd for each plant— at prices agreed upon for each shipment. Castro regime also outlawed all existing contracts between suppliers and retailers.

New Oil O.K. for Petrochemicals . . .

New oil discovery by Arabian Oil Co., Ltd., offshore from Neutral Zone will probably find ready market in Japan. Reasons: it's sweet (compared to other Middle East oil) and rather high in aromatics—ideal for Japan's booming petrochemical industry.

Quick Look At World-Wide Construction . . .

Polypropylene grows as Humble's Baytown unit goes on stream. Rated at 40 million lbs. yearly, new plant is largest of its type in the world . . . Foster Grant getting on polyolefin bandwagon with construction of multi-million-dollar high-pressure polymerization plant . . . American Gilsonite will double refinery capacity at Grand Junction, Colorado . . . New 50,000-bpd $30-million refinery now on stream at El Palito, Venezuela by Mobil Oil International affiliate . . . Cities Service Refining starts construction of $120-million-lb.-per-year ortho-xylene plant at Lake Charles.

Panning the Octane Scene . . .

Regular gasoline averaged 92.5 research octane last month—an increase of 0.1 over May. Premium held steady at 99.4.

Conoco Tests Third Brand . . .

Conoco now testing new third brand high octane (around 101.5) gasoline in Kansas, Nebraska, Iowa and Missouri—will evaluate public acceptance before extending to other states.

Plastics Market Grows . . .

Use of petrochemical polymers is growing trend in building industry—which even now uses thousands of tons of plastics yearly. Good example is plastic wall market which should reach $285 million by '69. Note of caution, however, came at recent CMRA meet when producers were warned to "go slow" and not introduce materials until they are completely tested. Said one expert, "Don't make the consumer part of the experiment."

Vehicle Registrations Climb . . .

Motor vehicle registrations last year in U.S. hit 71,502,394. This is gain of 4.3%, or about 3 million over '58. Breaks down like this: 56,-566,721 passenger cars, 265,114 buses, and 11,670,559 trucks. California was tops with 7.4 million vehicles. Second was New York with 5 million, then Texas and Pennsylvania with more than 4 million each.

Two Groups Studying Refinery . . .

Sterling Oil, new company promoted by Summit Corp. and backed by American Independent Oil, Phillips Petroleum and other interests, studying possibility of building refinery in South Vietnam. Also, three present S. Vietnam marketers, Standard-Vacuum, Shell Vietnam and Caltex, considering plan to build joint refinery there. French group was also interested but pulled out.

Petroleum Demand Forecast Drops . . .

This year's increase in petroleum demand won't rise above 3% says Chase Manhattan in revised forecast. First quarter hike was less than 0.5% with gasoline demand growing by only 1%.

Quick Look Around the World . . .

House passes and sends to Senate, helium conservation bill calling for 12 extraction plants on nation's gas lines . . . Since start of mandatory imports program, U.S. has paid $9.8 million more for petroleum products than it would have without the plan . . . Phillips Petroleum increases ownership of Union Oil to about 12%.

Diesel Gets Competition from Propane . . .

Diesel engines can be revamped to use liquid propane fuel according to recent findings of Southwest Research Institute. With propane costing less than half of diesel, railroads are showing considerable interest.

Army Reports on Fuel . . .

U.S. Army feels there is still much promise for wide-cut fuel—about 50% gasoline and 50% distillate—in compression-ignition engines being developed for combat equipment. Some feel it will be major energy source for Army engines for next 10 years. Gas turbines using same fuel also a good bet.

Tax May Affect Jet Requirements . . .

If current proposals to tax all avgas equally passes, jet planes may switch to gasoline-kerosine blend instead of present straight kerosine. Blend would probably be 65-75% gasoline—the rest kerosine.

UNRETOUCHED ACTION PHOTOS PROVE SUPERIOR PERFORMANCE OF BUELL CYCLONES

an ordinary cyclone

THE BUELL CYCLONE
with Shave-Off

These are photographs of as true a test as can be made under laboratory conditions. Notice the difference in the dust patterns! In the Buell Cyclone, on the left, the dust at the top makes less than one revolution before it is trapped by the Shave-Off. It's then channeled down to the lower portion of the Cyclone, well below the clean gas outlet.

Why is the Buell Shave-Off so effective? Primarily because it harnesses the double-eddy current to convey the dust "fines" downward quickly, thereby promoting greatly increased efficiencies. In the ordinary cyclone, as shown on the right, these "fines" concentrate and recirculate at the top, causing erosion of the cyclone. To be collected, the fine dust must travel downward close to the clean gas outlet where much of it escapes. Buell Cyclones have made an impressive record in many years of trouble-free service. To see how their extra efficiency in the Shave-Off can pay off for you, send for our Cyclone Catalog #103. The Buell Engineering Co., Inc., 123 William Street, New York 38, New York. Northern Blower Division, 6404 Barberton Avenue, Cleveland, Ohio. (Subsidiary: Ambuco Ltd., London, England.)

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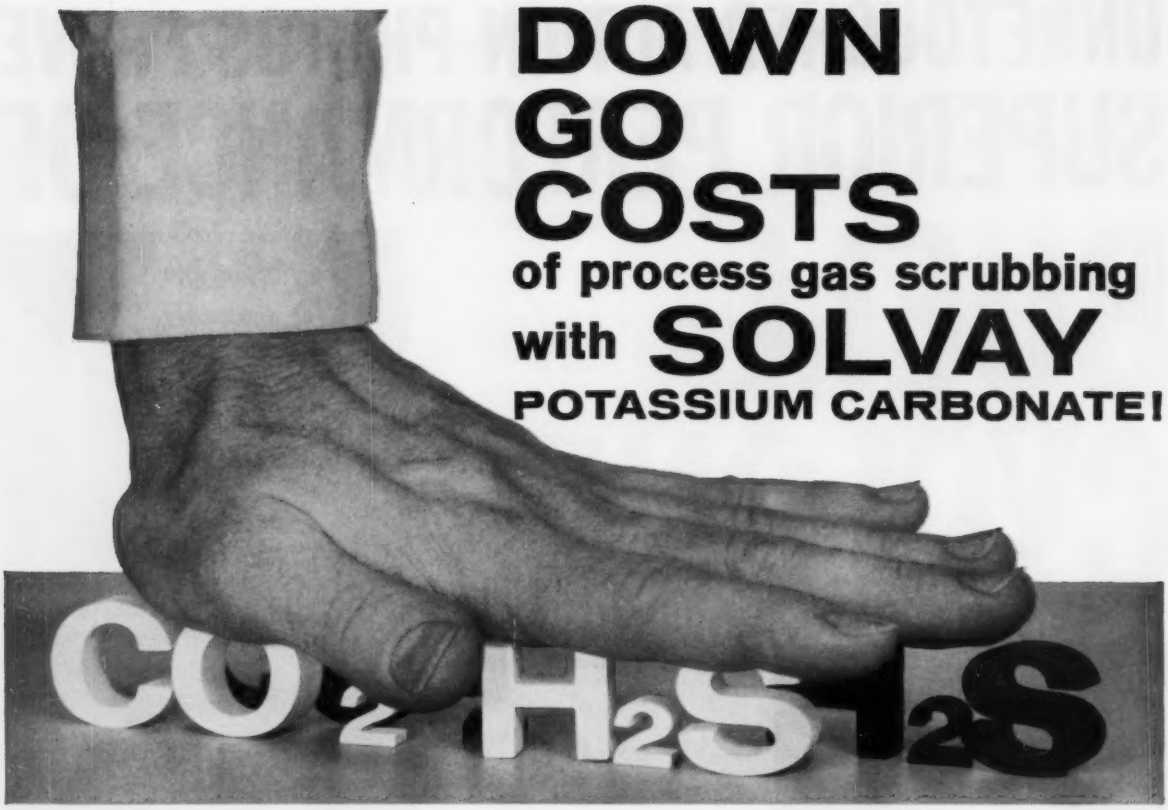

DOWN GO COSTS

of process gas scrubbing with SOLVAY POTASSIUM CARBONATE!

Save on utilities and fuel . . . purify process gases using the Hot Carbonate Process with Solvay® Potassium Carbonate. The hot circulating carbonate solution does away with costly heat exchangers and reduces steam requirements.

Wherever conditions of fairly high concentration and partial pressure exist, this is the most economical way to take out carbon dioxide from process gases. Applications range from ammonia synthesis to petrochemicals.

In natural gas treating, it is used to remove *both* carbon dioxide and hydrogen sulfide. Compare the potassium carbonate method's cost and economy with other gas-removal systems.

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- ☐ "For bulk removal of acid gases . . . Costs Favor Hot Carbonate Process" —Chemical Engineering.
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- ☐ "Economics of Acid-Gas Removal"—Oil and Gas Journal.
- ☐ "Improved Process for CO_2 Absorption"—Chemical Engineering Progress.
- ☐ "Hot Potash Process for Gas Purification"—Oil and Gas Journal.
- ☐ "Which CO_2 Removal Scheme Is Best?"—Petroleum Refiner.
- ☐ "New Potassium Carbonate Process"—Petroleum Refiner.
- ☐ "Solvay Potassium Carbonate" fact book.

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68-60

How Politically Potent Are You?

THE RECENT DECISION of Continental Oil Co. to give employes time off from work to carry on political party activities certainly comes as a pleasant bit of information. Of course, individual companies such as Conoco, Gulf, Tennessee Gas and many others have been conducting political education programs for employes for more than a year now. However, to our knowledge this is the first time that a company has gone so far as to say that an employe will be let off for party activities—without a loss in pay.

Specifically, the Conoco policy applies to employes who have been elected and are serving as officers at the precinct level or above in both major parties. It also applies to elected delegates who will be given time off, not exceeding three days, to attend conventions. Time will also be granted any employe who is a party officer to conduct election day activities.

This attitude of Conoco, and the attitude of the other organizations which have decided that politics can be brought out into the open and discussed intelligently is certainly healthy for all Americans. However, this brings to mind one important question which we all should stop and consider for a moment. That is, in view of this accelerated tempo of political education, what are you doing on your own to increase your knowledge of politics, politicians and national issues?

Individual Effort. Your company can expose you to basic politics and how this government functions, and perhaps to some of the important issues as they arise from time to time. But to be politically potent—to be able to form an intelligent opinion of candidates and issues based on facts, the individual must put forth some extra effort.

There are those in this country, you know, who feel that the government must do the planning for the people. We feel, however, that the reverse is true, and that the individual should make his own plans; that an amalgamation of these many individual plans should be the basis for our government. However, for this doctrine to be effective, each person is going to have to keep informed on major issues.

But now, let's pause for a moment to let you ascertain your own political IQ. We are concentrating in the area of petroleum, because after all, we are an oil publication—and you are part of the oil industry. Therefore, we have borrowed this questionnaire from the Texas Mid-Continent Oil and Gas Association Public Affairs Conference. See how you rate!

1. What county do you live in?_____ County.
2. Are you a registered voter for 1960? (Check one.) In some states this means, "Did you pay your poll tax?" Yes_____ No_____
3. Write the last name of the U.S. Congressman from your home district. _____
4. Write the names of three representatives in your state legislature.
   1. _____
   2. _____
   3. _____
5. What is the total state and federal tax per gallon of gasoline in your state?_____
6. What is the rate of state severance tax on production of crude oil in your state?_____
7. Have you written a personal letter to a member of Congress in the last year on
   1. Fuels policy resolution? _____Yes _____No
   2. Percentage depletion? _____Yes _____No
   3. Gasoline taxation? _____Yes _____No
   4. Natural gas regulation? _____Yes _____No
   5. Labor legislation? _____Yes _____No
   6. Any other subject? _____Yes _____No
8. Have you written a letter to a member of your state legislature about an oil or gas industry issue within the past year? _____Yes _____No
9. Do you belong to a civic club (such as Rotary, Lions, etc.)? _____Yes _____No
10. In Presidential elections, do you usually regard yourself as a_____Democrat, _____Republican, or_____Independent. (Check one.)
11. Have you ever worked as a campaign volunteer in behalf of any political party or candidate?
    _____Yes _____No
12. What kind of a job do you feel your employer does in keeping you informed on oil and gas industry affairs?
    _____Good _____Poor _____Fair
13. Generally, what attitude do you think the following persons have toward the oil and gas industry? (Check one.)

	Friendly	Unfriendly	Don't Know
Chet Huntley			
William Proxmire			
Lyndon Johnson			
Dwight Eisenhower			
David Brinkley			
Jerome K. Kuykendall			
Frank M. Porter			
Paul Douglas			

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J&L Electricweld pressure tubing is subjected to precise checks at every stage of production, from the basic steelmaking process until the tube is ready for shipment. This series of critical examinations on every length of tubing—inside and out—assure you of perfect field performance. Further details of Electricweld tubing and the economies it offers compared with seamless are available on request from J&L—creator and producer of *unmatched* Electricweld tubing.

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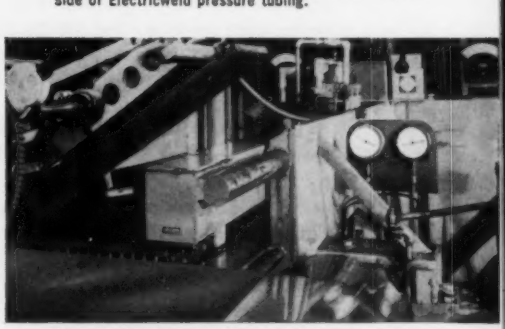

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Matthew V. Carson, Jr.	_____	_____	_____
Richard Nixon	_____	_____	_____
Douglas Edwards	_____	_____	_____
M. J. Rathbone	_____	_____	_____
Oren Harris	_____	_____	_____
Ralph Yarbrough	_____	_____	_____

14. Who would you say is the best known oil man in your city? _____

15. Have you made a speech before any sort of public gathering concerning the oil and gas industry within the past two years? _____Yes _____No

16. Do you recall reading or hearing of anyone in your company making a speech on an oil and gas industry subject during the past year? _____Yes _____No
If "yes," who was the speaker?_____
_____

Now, we're not going to say if you scored real high you ought to be in politics or if your score was pretty low you should hang your head in shame. All we want to do here is to give you some kind of idea of how well you have been keeping up with politics, as applied to the industry you know best—the oil industry.

Next month we'll bring you a few facts and figures compiled by the Texas Mid-Continent Oil and Gas Association on other oil men who have filled in this questionnaire. We'll also present some information on the 30 Senators who are running for re-election in November, plus how they voted on certain issues pertinent to the oil and gas industry.

But before next month, why don't you pick up a pencil and paper and see how many important oil issues that came up for Congressional vote you can name. Then write down how you think your Congressmen voted on them. And after you've done these things—after you have taken stock of your knowledge of the issues that are important to the industry that pays your salary each month, ask yourself these two questions: "How well did I do?" "How well should I have done?"

Is Your Product Needed?

"TO REMAIN WEDDED to volume alone as a criterion of performance is sheer folly. Disregarding the true market demand is a luxury no one can afford for long. The 'incremental throughput' philosophy has spread like a virus throughout our industry. It has colored our judgment and weakened perspective." These observations had men sitting on edges of their seats at last month's API meeting, as M. J. Rathbone, president of Standard Oil Co. (New Jersey) delivered a sizzler to refiners—urging them to "think and operate as businessmen."

Rathbone seemed thus to crystallize the ills of today's refining industry: "We still seem to run our refineries as a tool to convert crude oil into products, with apparently no one really being responsible for determining whether all the products are needed or whether they can be sold at a profit."

Since mid-1955, refining capacity in the rest of the world has exceeded that in this country. This decrease in relative supremacy for the United States has been coming on for some time now. Foreign countries have been adding capacity at about twice the rate of U.S. growth for at least the past 10 years (PR, p. 203, April 1959). This growth is not warranted by the demands for refined products. For example, a little more than 90 percent of refinery capacity was being used to satisfy product demand during the early 1950s. This is about the maximum a refiner can use because of necessary repairs and turnarounds. Now, by contrast, crude runs to stills take up only about 80 percent of the available U.S. refinery capacity.

Refiners must study oil economics and *use* that knowledge to orient thinking to market demand. For if this is not done, they certainly can't expect the immediate future to be any brighter than the past few years.

PR Awarded Another Star

FOR THE SECOND YEAR in a row, PETROLEUM REFINER has been awarded a Public Interest Award from the National Safety Council. The award is based on our fine record in 1959 of presenting material relating to achieving better safety practices in the oil, gas and petrochemical processing industry. PETROLEUM REFINER was the only oil publication to receive such an award which is presented to recognize and honor exceptional service to safety in the public information field. "Performance well above the average, qualitative as well as quantitative," the notification explained, "leadership, initiative and originality. It means a continuous—not a sporadic—effort."

Umbach

"We who are concerned with safety on a 24-hour basis do appreciate, perhaps more than the general public, the time, effort, and money your contributions represent in the field of safety," Val Jean McCoy, chairman of the Houston Traffic Safety Commission said in a congratulatory note. "It is a pleasure to be associated with people such as your editors in this unending safety campaign which represents such a challenge to the best efforts of every American community."

This safety work which over the years has claimed much PETROLEUM REFINER attention and space comes within the province of Clayton Umbach Jr., our management and personnel editor. It is he who follows latest developments along this line and selects and prepares the material which is published.

Above and beyond the pride which naturally accompanies receipt of such an award is an even better feeling that comes with the knowledge that through our efforts, PR almost certainly has helped prevent more than a few accidents.

How to handle TEL susceptibility in linear programming of gasoline blending studies

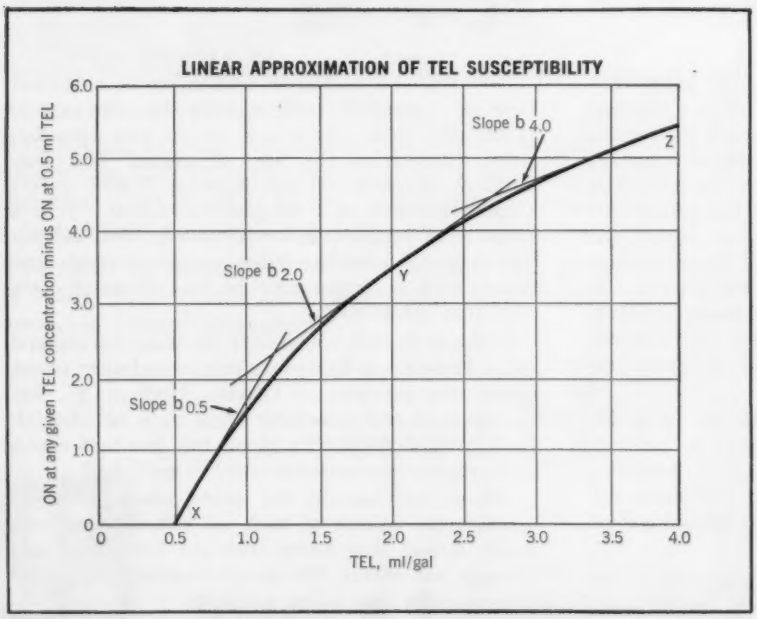
By Dr. W. C. Healy, Jr., Supervisor of the Computation and Economics Section, Refinery Technology Division, Ethyl Research Laboratories

In past years, gasoline blending was comparatively simple. An engineer could establish optimum blends for two grades of gasoline by using a slide rule and a TEL response chart.

Today gasoline blending and establishing maximum antiknock effectiveness are much more complex. Many components are used to make numerous grades of gasoline. Often, market conditions divert some gasoline component to another product. All this presents the refiner with a giant-sized problem of blending for maximum profit.

The magnitude of the problem has forced the refiner to electronic computer solutions, using such techniques as linear programming.

Because TEL susceptibility is a non-linear function, it presents a special problem for computer studies when linear programming is used. Many suggestions have been made for handling the TEL function, and one of the simplest recorded to date is outlined here.



The Ethyl method of handling the TEL function is similar to others in that a target TEL susceptibility curve is approximated by straight-line segments having fixed slopes. However, it is easier to use because—

A. No extra variables are introduced.

B. No extra upper-bounding conditions are required.

C. Set-up time is reduced.

Calculating TEL linear approximations is not difficult when final blend TEL susceptibility* is known. It becomes difficult when susceptibility is to be determined by computer. Calculations must employ approximated susceptibility values while retaining accuracy for reasonable deviations.

*TEL susceptibility is here defined as the difference between octane numbers at 4.0 ml. TEL/gallon and at 0.5 ml. TEL/gallon.

For more data on advertised products, use Readers' Service Cards, last page.

Here's How Ethyl's Method Works

For example, in the figure, three line segments are used to approximate the curve. The procedure is as follows:

A. Estimate a blend TEL susceptibility curve and then plot on rectangular coordinate paper.

B. Draw three approximating lines so that one line passes through point X (0.5, ON at 0.5), the second line passes through Y (2.0, ON at 2.0), and the third line passes through Z (4.0, ON at 4.0).

C. Determine the slopes of these approximating lines, $b_{0.5}$, $b_{2.0}$, and $b_{4.0}$, as shown on the accompanying chart.

Then the following inequalities are required; they state that the ml. TEL per gallon shall be no less than that required on any line segment, and no greater than 4.0.

1. $\text{TEL} \geq \frac{\text{ON (specification)} - \text{(ON at 0.5)}}{b_{0.5}} + 0.5$

2. $\text{TEL} \geq \frac{\text{ON (specification)} - \text{(ON at 2.0)}}{b_{2.0}} + 2.0$

3. $\text{TEL} \geq \frac{\text{ON (specification)} - \text{(ON at 4.0)}}{b_{4.0}} + 4.0$

4. $\text{TEL} \leq 4.0$

Let

$X_1, X_2 \cdots X_n$ = Barrels of each component in the blend.

ON_i at 0.5 = Corresponding octane blending values at 0.5 ml. TEL/gal.

ON_i at 2.0 = Corresponding octane blending values at 2.0 ml. TEL/gal.

ON_i at 4.0 = Corresponding octane blending values at 4.0 ml. TEL/gal.

And $Y = (\text{TEL})(\Sigma X_i)$

Ther substitute in 1, 2 and 3 above

$$\text{ON at } 0.5 = \frac{\Sigma X_i (ON_i \text{ at } 0.5)}{\Sigma X_i}$$

$$\text{ON at } 2.0 = \frac{\Sigma X_i (ON_i \text{ at } 2.0)}{\Sigma X_i}$$

$$\text{ON at } 4.0 = \frac{\Sigma X_i (ON_i \text{ at } 4.0)}{\Sigma X_i}$$

and multiply 4 by ΣX_i

These inequalities then reduce to the required linear expressions:

5. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 0.5 + 0.5\, b_{0.5}) - b_{0.5} Y \leq 0$

6. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 2.0 + 2.0\, b_{2.0}) - b_{2.0} Y \leq 0$

7. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 4.0 + 4.0\, b_{4.0}) - b_{4.0} Y \leq 0$

8. $Y - 4.0 \Sigma X_i \leq 0$

Under certain conditions the number of inequalities may be reduced to three or less.

Susceptibility Changes Are Compensated

Error-compensation is a built-in feature with this method since, when blend susceptibility varies (higher or lower) from the estimated value, the line segments adjust themselves to the proper portion of the new curve.

For greater accuracy, more than three line segments may be used to approximate the susceptibility curve. This requires additional analogous inequalities, but no additional variables.

Each additional octane specification calls for an estimated susceptibility curve and the statement of inequalities as shown above.

Checking the program before the computer run.

How Ethyl Research can help you

Ethyl Research has several years' experience with linear programming as it applies to gasoline blending. This background has been especially valuable for customer service work.

The new method of handling tetraethyllead susceptibility is one example of the professional assistance available to the refiner from Ethyl.

In addition, the Computation and Economics Section in our Refinery Technology Division will be glad to share its experience in computation techniques with your people.

For further information, ask your Ethyl Representative for a copy of "Two Approximation Problems in Linear Programming of Gasoline Blending" presented at the Computer Conference of the WPRA in Tulsa, December 1, 1959. He'll also be glad to arrange an appointment for you with one of our Mathematical Analysts.

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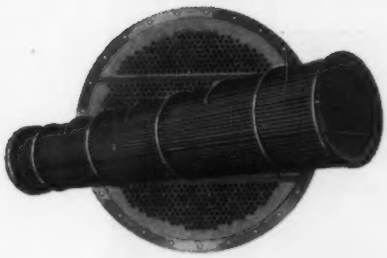

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insures maximum efficiency and dependability for BRYAN, TEXAS, MUNICIPAL POWER PLANT

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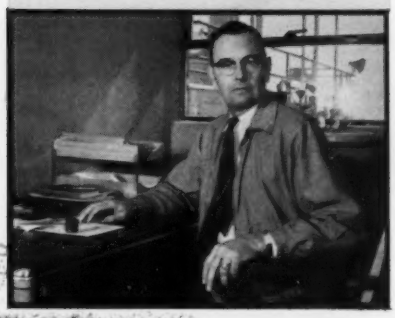

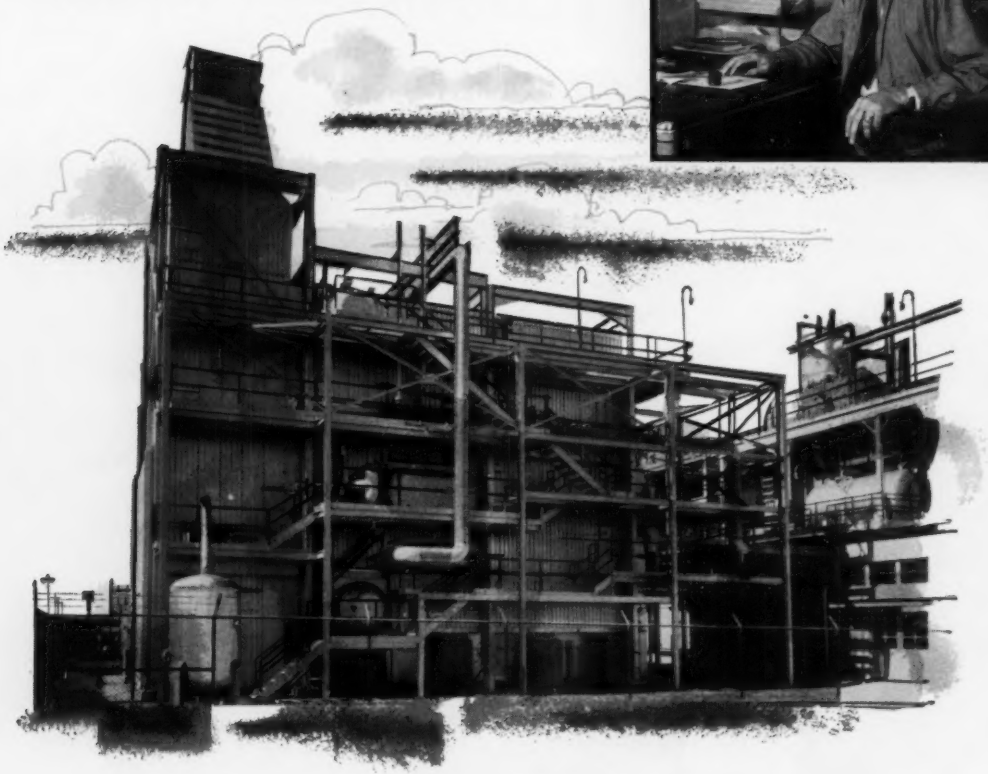

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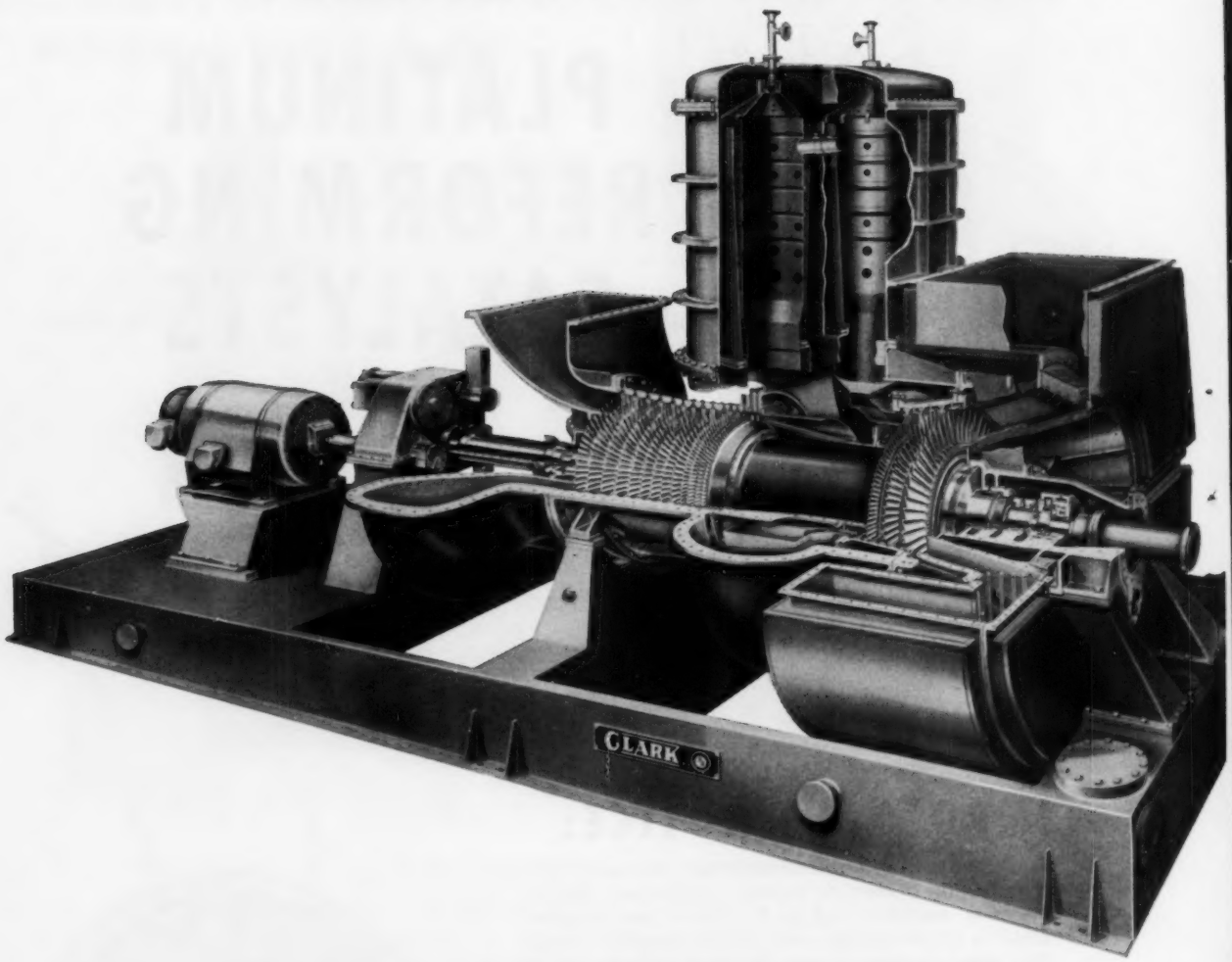

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Name the norm . . . capital investment, floor space, installation or operating labor, general reliability, maintenance or all combined. Whatever you use to determine *real* prime mover cost, Clark heavy duty industrial gas turbines provide the most economical answer to your requirements. As an example of how these advantages work for you let us examine the latest addition to the Clark 300 series of turbines, the Model 305-S.

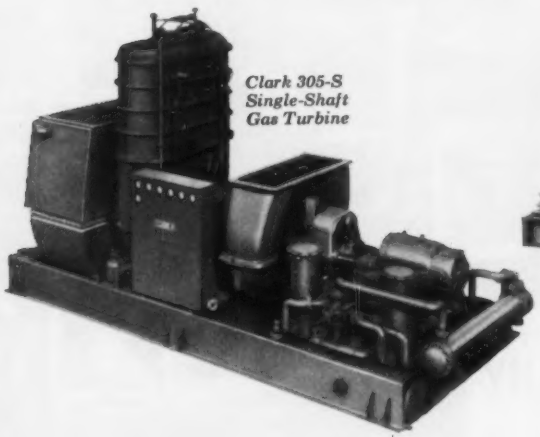
CONSIDER INITIAL INVESTMENT—This single-shaft open cycle machine is simplicity itself. With the axial compressor and three stage turbine mounted on the same shaft, parts . . . *and cost* are cut to a minimum.

FIELD PROVED RELIABILITY—Important components such as compressor and turbine blading are based on proved designs which have operated for thousands of hours in Clark Dual-Shaft Gas Turbines. Turbine inlet temperature is held under 1400° F to ensure extra long life and to provide a substantial margin of operating safety. The turbine is completely air cooled and suitable for operation in arid country. Pressurized air is bled off the axial compressor to cool turbine blade roots and other high temperature components. In addition, cool air envelopes between inner and outer skin surfaces reduce heat loss and minimize heat radiation.

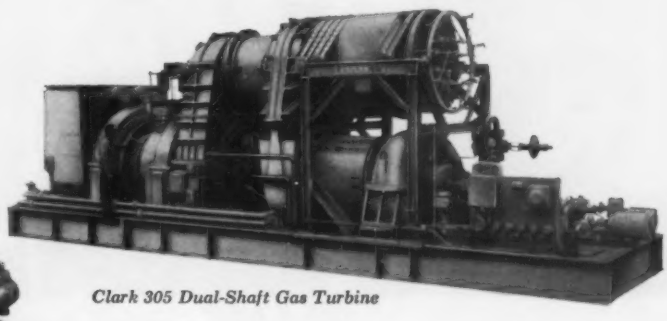
FLOOR SPACE INSTALLATION AND MAINTENANCE—The Clark 305-S is so compact it is mounted on a skid only 26 feet long. The combustion chamber with two parallel burners is placed over the rotor between compressor and turbine. You save on floor space, housing, transportation to the site, foundation and installation expense. Both the single and dual-shaft Clark gas turbine designs have provisions for easy access to blading, bearings and seals for inspection or maintenance.

VERSATILE TOO—Clark Series 300 Gas Turbines in the 8000-10,000 horsepower class provide the inherent flexibility to match the application. The dual-shaft models are excellent drivers for pumps or compressors on liquid or gas transmission lines, for marine propulsion, compressor drivers in repressuring or process plants and other uses requiring broad speed and loading flexibility. For applications that do not require the wide range flexibility of the dual-shaft machine such as base load or peaking turbogenerators the single-shaft units are ideal. Both designs burn either liquid or gaseous fuels.

Your Clark representative will gladly give you all of the cost saving details on Clark Gas Turbines. Consult him or write us direct. CLARK BROS. CO., OLEAN, NEW YORK.



Clark 305-S Single-Shaft Gas Turbine



Clark 305 Dual-Shaft Gas Turbine

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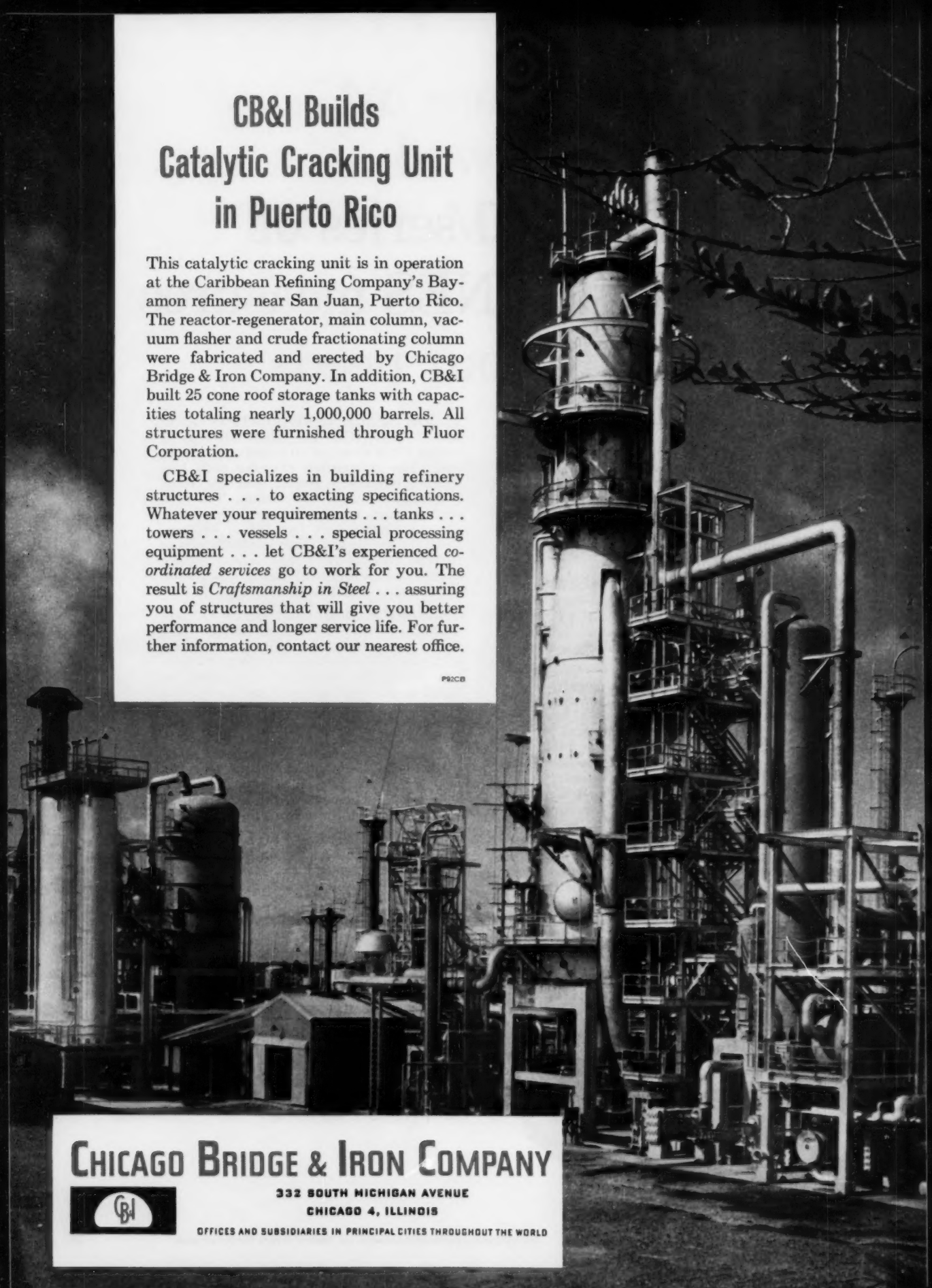
CB&I Builds Catalytic Cracking Unit in Puerto Rico

This catalytic cracking unit is in operation at the Caribbean Refining Company's Bayamon refinery near San Juan, Puerto Rico. The reactor-regenerator, main column, vacuum flasher and crude fractionating column were fabricated and erected by Chicago Bridge & Iron Company. In addition, CB&I built 25 cone roof storage tanks with capacities totaling nearly 1,000,000 barrels. All structures were furnished through Fluor Corporation.

CB&I specializes in building refinery structures . . . to exacting specifications. Whatever your requirements . . . tanks . . . towers . . . vessels . . . special processing equipment . . . let CB&I's experienced *coordinated services* go to work for you. The result is *Craftsmanship in Steel* . . . assuring you of structures that will give you better performance and longer service life. For further information, contact our nearest office.

P92CB



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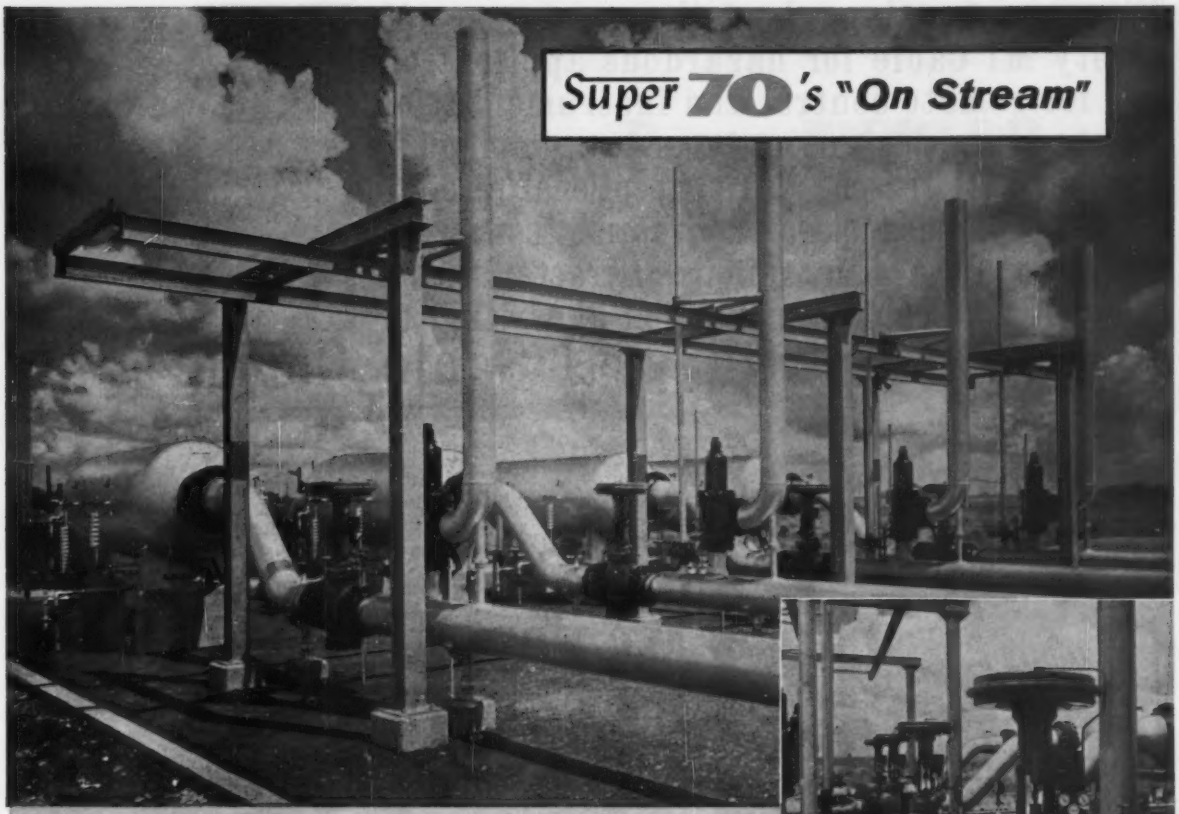

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BS&B Super 70 Diaphragm Control Valves with Clamp Ring—Float Ring Body Closure.

This natural gas metering station feeds 100 MMSCF of gas per day to a large Gulf Coast Refinery. If it were necessary to shut down the station for repairs, operation of the refinery would be seriously impaired.

That's why engineers who designed the station wanted to be absolutely sure the control valves would function properly day in and day out under all operating conditions.

Because of their superior performance characteristics and rugged dependability . . . and because of BS&B's reputation for quality products and dependable service in the oil industry . . . BS&B Super 70 Control Valves were selected. Now "on stream", they are performing well in every respect.

BS&B Super 70 Valves are available in a complete range of sizes . . . with either clamp ring—float ring, or flanged—gasketed body closures. Specify them on your next job!

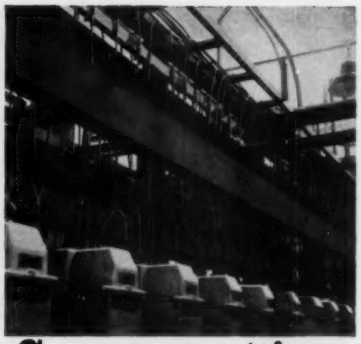
BLACK, SIVALLS & BRYSON, INC.

Controls Division,
Dept. 4-F6
7500 East 12th Street
Kansas City 26, Missouri

SUPER BS&B 70

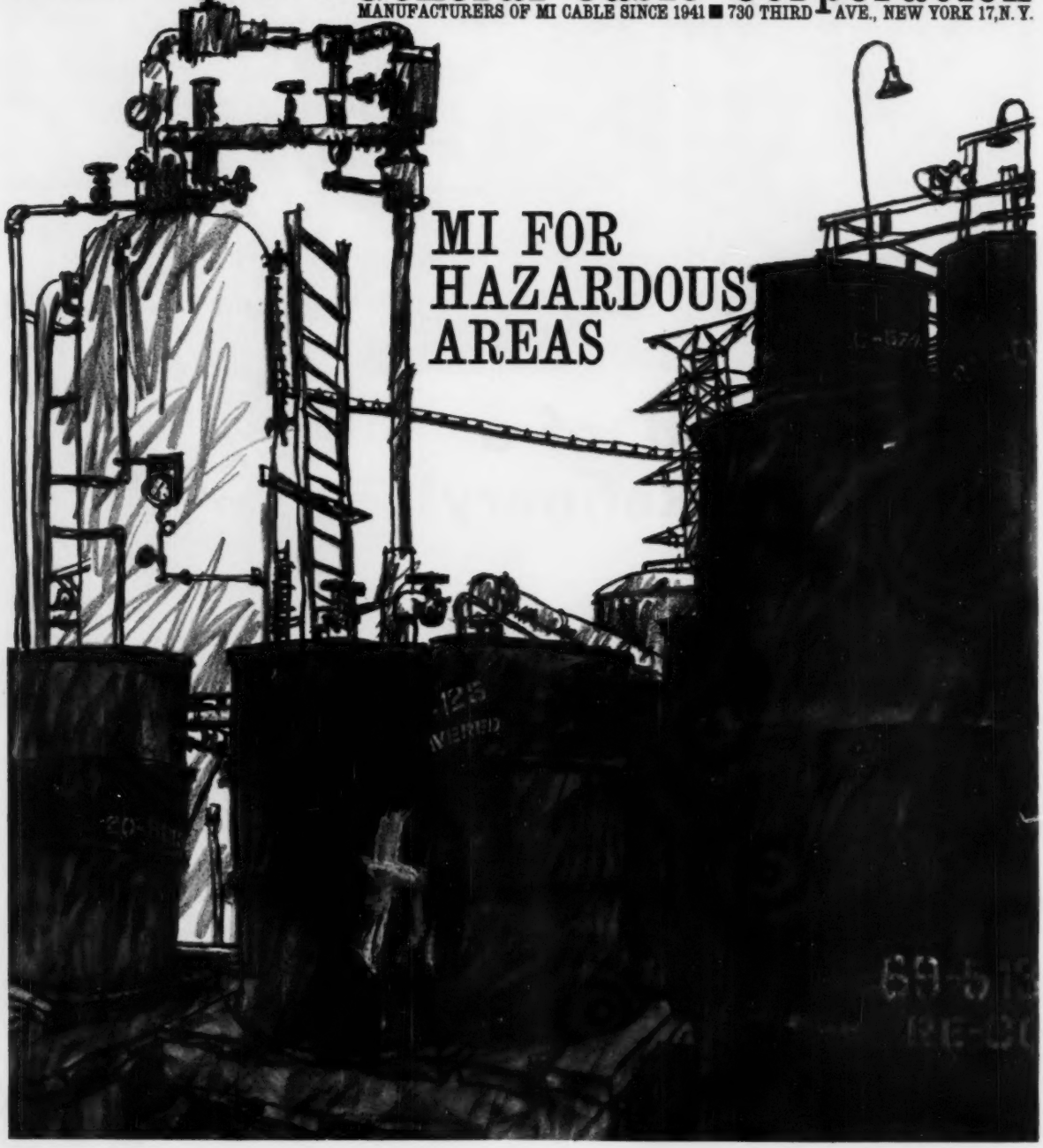
For more data on advertised products, use Readers' Service Cards, last page.

Oil companies throughout the country specify Safety MI Cable for hazardous applications and for remote control and instrumentation. Outstanding design engineers recommend it. One four-part reason... MI's exceptional record of safety, efficiency, permanence and economy. ■ Investigate the many unique characteristics of this versatile cable construction by writing for the new MI catalog



General Cable Corporation

MANUFACTURERS OF MI CABLE SINCE 1941 ■ 730 THIRD AVE., NEW YORK 17, N. Y.



Pacific Process Pump **EXTRAS** bring **EXTRA PROFITS** to you!

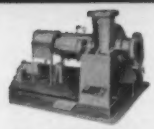
EXTRA CORROSION ALLOWANCE—All Pacific Process pumps are custom-built with case casting thickness in excess of actual pressure-temperature requirements. This provides a liberal allowance for corrosion-erosion and a high safety factor.

EXTRA HEAVY CONSTRUCTION—Pacific process pumps are engineered to combine the strength necessary for continuous heavy duty service with design simplicity and accessibility for low maintenance cost. All parts in contact with pumped liquid may be fabricated from any commercially available ferrous or non-ferrous metal.

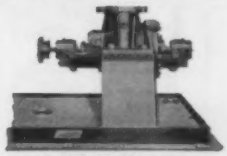
EXTRA LONG LIFE—Guided inlet flow reduces friction losses—insures minimum required NPSH. Dynamically, radially, and axially balanced moving parts eliminate vibration that would cause damage to rings, bushings, bearings, packing or mechanical shaft seals and excessive radial and thrust loads on bearings. Result—greatly increased availability for profitable operation.

Write for bulletins—please specify pump type.

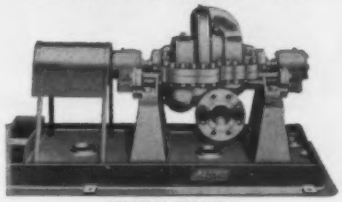
MAXIMUM PARTS INTERCHANGEABILITY
is an extra feature in
PACIFIC PROCESS PUMPS



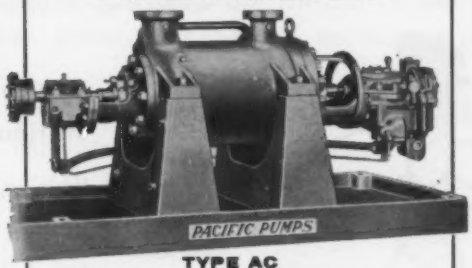
TYPE SVC
To 850°F.—25 to 3200 GPM
To 600 PSIG—To 650 DIFF. HD. FT.



TYPE HVC
To 850°F.—600 to 4500 GPM
To 600 PSIG—To 1000 DIFF. HD. FT.



TYPE RHC
To 500°F.—50 to 3000 GPM
To 700 PSIG—To 1300 DIFF. HD. FT.



TYPE AC
To 850°F.—100 to 2500 GPM
To 1000 PSIG—To 2600 DIFF. HD. FT.

PACIFIC PUMPS INC
A Division of Dresser Industries, Inc.
HUNTINGTON PARK, CALIFORNIA

PACIFIC®

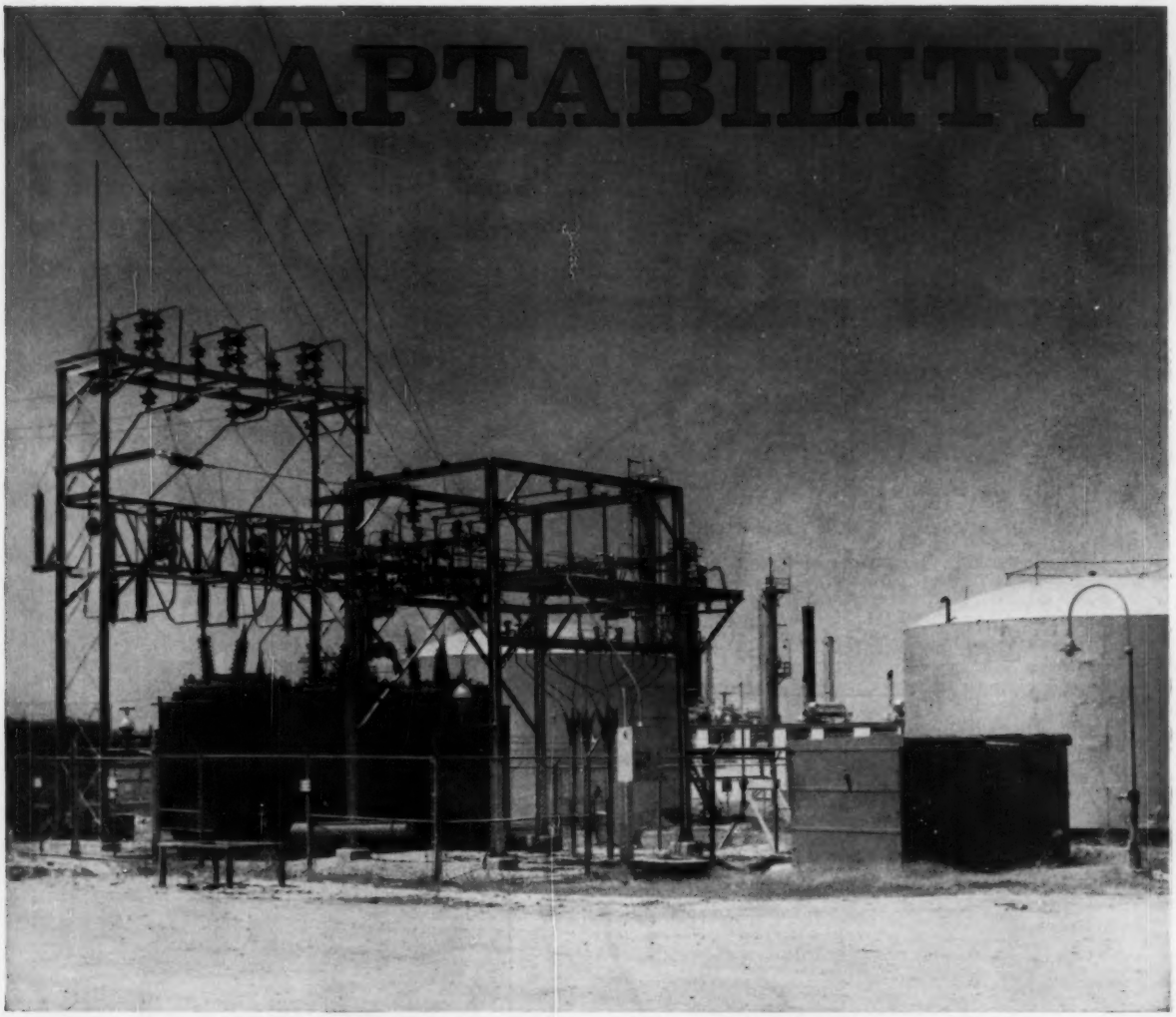
Offices in All Principal Cities

CP-10

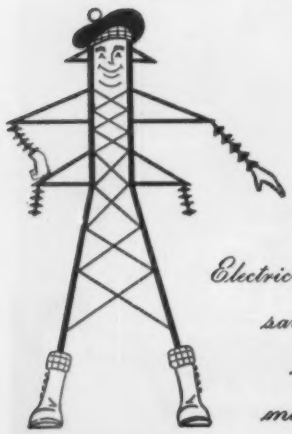
For more data on advertised products, use Readers' Service Cards, last page.

You can depend on purchased electric power for

ADAPTABILITY



This mainline crude oil station was converted to purchased electric power.



Purchased Electric Power . . . saves money, manpower, maintenance, and serves you better automatically

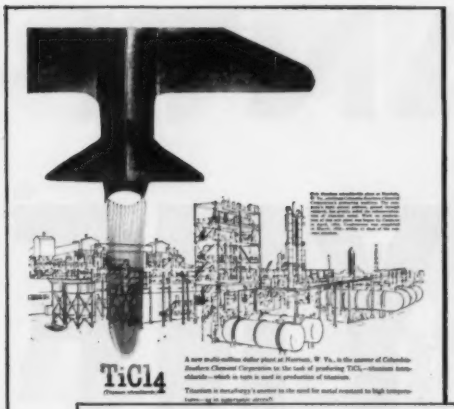
Typical of money saving installations is this new crude station using utility electric power

This modern station using three 500 hp and two 150 hp motors and 22 electrically operated valves is evidence of the trend to purchased electric power for ultimate economy. Whether your operation is pipeline, refinery or production it will pay you to investigate the possible savings of utility electric power. Call your nearest utility electric power company today.

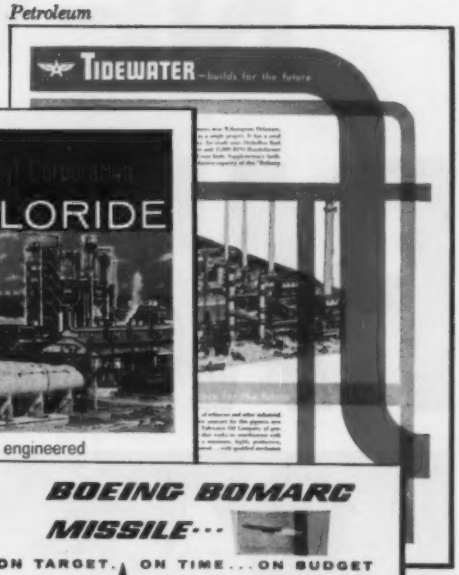
Petroleum Electric Power Association P.O. BOX 35006, DALLAS 35, TEXAS

For more data on advertised products, use Readers' Service Cards, last page.

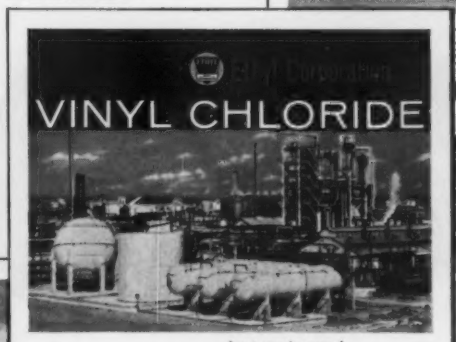
Metallurgy



Petroleum



Petrochemical



Pennsalt Chemicals
CREATED
in only 8 months at 10 per cent under budget
10% UNDER BUDGET—Pennsalt Chemicals Corporation's new Methylamines plant was completed by Catalytic, Engineers—Constructors, at a figure ten per cent under the original estimated cost.
AHEAD OF SCHEDULE—The Methylamines plant was completed and ready for start-up in only eight months after the start of engineering. This "On-Time" completion was in advance of the requirements of Pennsalt Chemicals Corporation.
UNDIVIDED RESPONSIBILITY—Centralized control and coordination of all phases of this project and close cost, various with the client were prime factors in the successful completion. This Methylamines plant again proved Catalytic's ability to render all client services "On-Time, On-Budget".
CATALYTIC
CONSTRUCTION COMPANY

Chemical

Defense

VERSATILITY... Engineering, construction and maintenance accomplishments in a variety of specialized fields demonstrate the versatile part CATALYTIC plays in today's industry.

Our scope includes complete technical services for the petroleum, petrochemical, chemical, metallurgical, nuclear and defense industries.

Our reputation—"On Time—On Budget."

CATALYTIC

CONSTRUCTION COMPANY

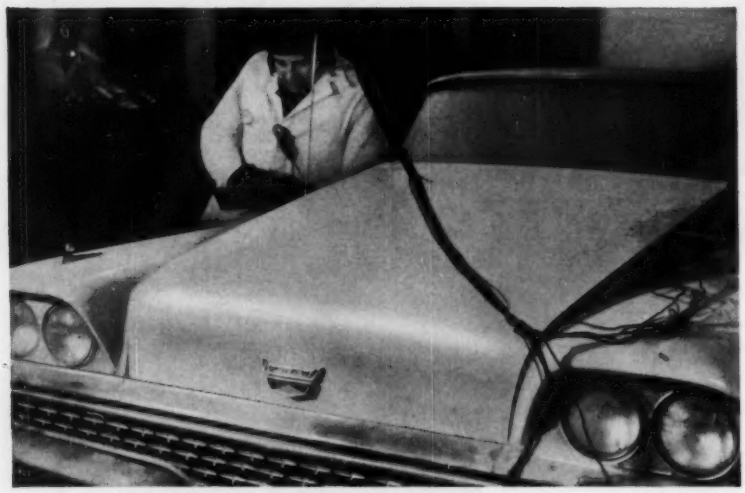
PHILADELPHIA 2, PENNSYLVANIA

In Canada: Catalytic Construction of Canada, Limited; Sarnia, Ontario

For more data on advertised products, use Readers' Service Cards, last page.

NEW ANTI-

PARADYNE®



PARADYNE 41 PASSES STIFF ANTI-STALLING TESTS

The photograph shows a car undergoing stalling tests in a controlled temperature room. Paradyne 41 inhibited gasoline gave outstanding performance under the most critical conditions.

provides maximum protection against engine stalling

Paradyne 41 prevents troublesome carburetor icing . . . the most common cause of stalling in the fall, winter and spring seasons. A combination of phosphorus-containing compounds, Paradyne 41 forms a protective water- and ice-repellent film on metal surfaces . . . preventing agglomeration of ice crystals on carburetor surfaces.

ALSO PREVENTS RUST

Test panels immersed in Paradyne 41 inhibited gasoline showed no rust after 40 days.

SAVES MONEY ON PHOSPHORUS

At concentrations normally used for anti-icing, Paradyne 41 provides an appreciable portion of the phosphorus required to modify combustion deposits...thus reducing the amount of additional phosphorus additive required to prevent misfiring and surface ignition.

PERFORMANCE PROVEN BY THOROUGH FIELD TESTING

Extensive field tests, closely controlled test car studies and large-scale distribution studies . . . substantiate service qualities shown by Paradyne 41 in laboratory test engines.

EASY STORAGE AND HANDLING

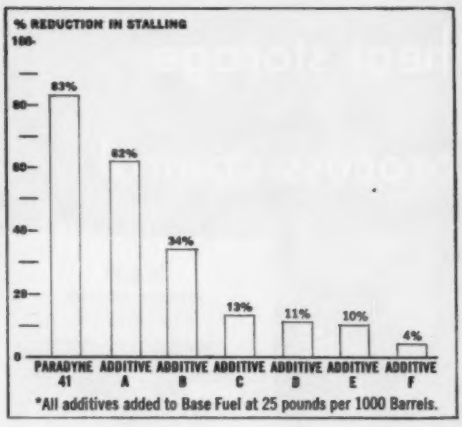
May be handled as a petroleum product . . . with normal precautions used in handling phosphorus additives.

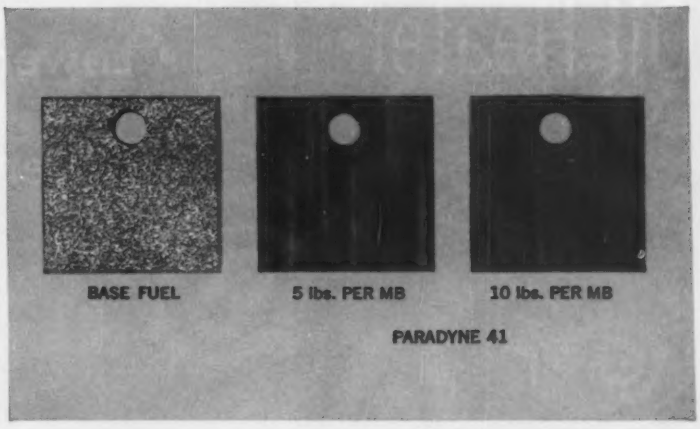
ENJAY

ADDITIVES

For more data on advertised products, use Readers' Service Cards, last page.

STALL 41 GASOLINE ADDITIVE!





PARADYNE 41 PROVEN SUPERIOR

The bar chart shows the anti-stalling effect of Paradyne 41 and six other leading additives when compared with the additive-free gasoline. Under test conditions, additive-free gasoline allowed 22 out of 25 possible stalls. Paradyne 41 reduced the stalls to less than four out of 25 – a reduction of over 83%. Paradyne 41 excels in anti-icing effectiveness even under the most critical temperature and humidity weather conditions.

CALL UPON ENJAY FOR PRESCRIPTION-BALANCED ADDITIVES THAT

...meet your exacting specifications
...help you market your products successfully

The new Paradyne 41 Technical Service Bulletin, and information about improving your product's performance with a Prescription-Balanced Paramins Package, are yours for the asking.

TEST PANELS SHOW PARADYNE 41 ANTI-RUST EFFECTIVENESS

Rusted panel at left was immersed in gasoline over synthetic sea water for three days. The other panels were subjected to same conditions for 40 days, but gasoline was inhibited by small concentrations of Paradyne 41. Note that these panels are rust free.

ENJAY SERVES YOU

...with a *complete* line of petrochemicals to improve fuels and lubes • with a larger staff devoted exclusively to additives research and manufacture ... a staff available to help you meet your special additives requirements • with quality controls at every production step to assure that each order meets specifications • with expedited deliveries from Enjay product centers across the country.

Want more information? Contact the nearest Enjay office: (Home Office) 15 West 51st Street, New York 19, N.Y. (Other Offices) Akron • Boston • Charlotte • Chicago • Detroit • Houston • Los Angeles • New Orleans • Tulsa • Toronto

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

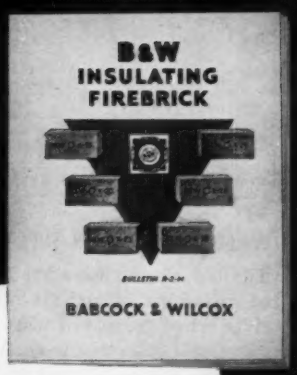
A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY
ADDITIVES

For more data on advertised products, use Readers' Service Cards, last page.

Why B&W IFB for Oil Heater Linings ?

- Lightest weight
- Simplified construction
- High hot load strength
- Lower conductivity
- Lower heat storage
- Better process control



The light weight of B&W Insulating Firebrick provides savings in capital investment in several different ways. The light weight of B&W IFB permits thinner wall constructions of equivalent insulating value. These thinner, lighter walls mean real savings in structural steel and concrete. Construction is further simplified because B&W IFB's high hot load strength makes possible higher unsupported walls without deformation at furnace operating temperatures. In addition B&W IFB can be cut and shaped with ordinary wood working tools, simplifying field installation.

The light weight of B&W Insulating Firebrick also provides the greatest insulation. Thus, they save more fuel.

Light weight also means lower heat storage. B&W IFB protect you against burn-out of expensive alloy tubing in the event of forced shutdown. B&W IFB respond faster to changes in firing rate, too, assuring you of more positive process control.

**Write for Bulletin R-2-H giving more data on B&W Insulating Firebrick.*

B&W

THE BABCOCK & WILCOX COMPANY

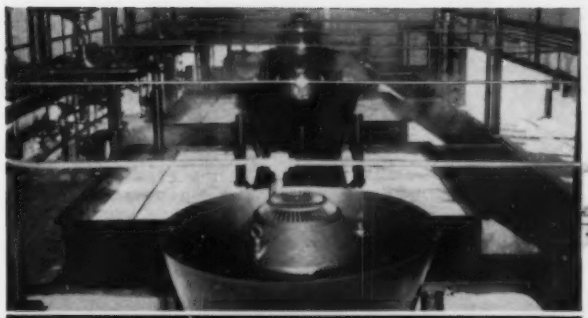
REFRACTORIES DIVISION

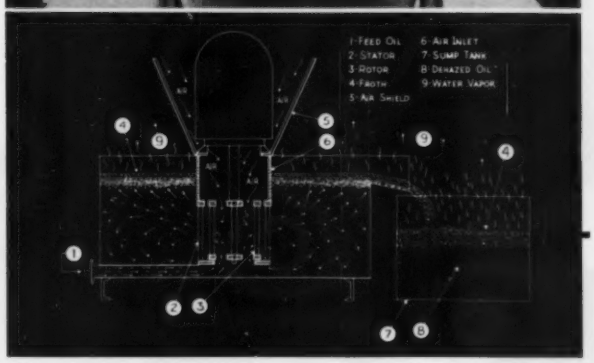
B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

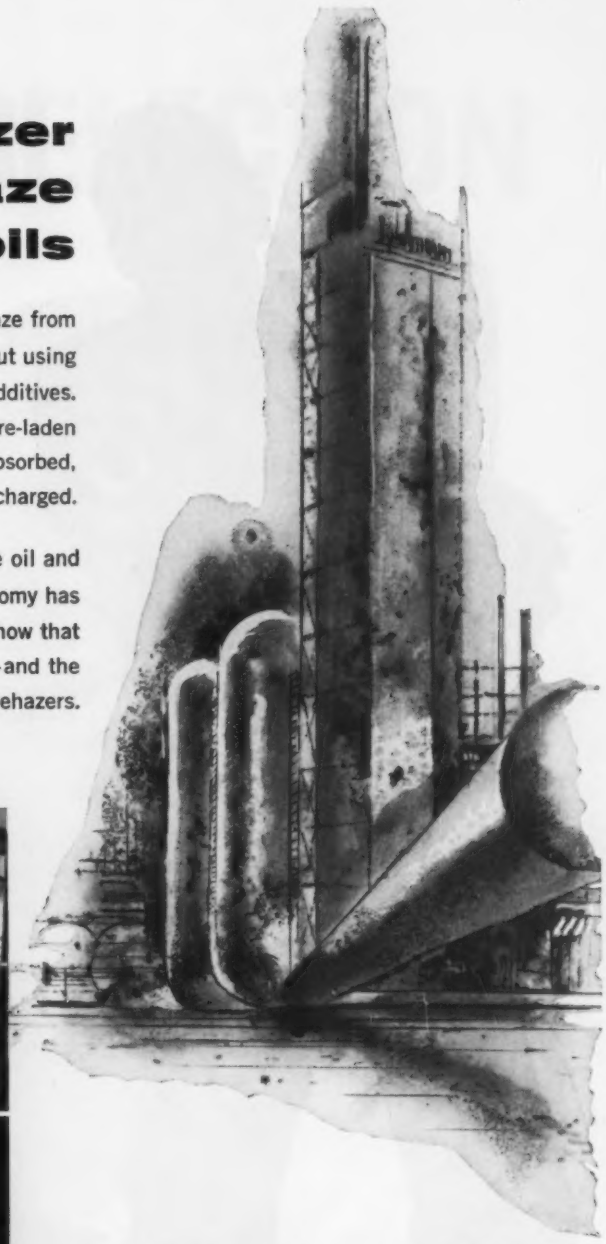
Hendrick dehazer lifts the haze from refinery oils

The Hendrick Hydro-Dehazer removes haze from refinery oils quickly and economically, without using compressed air, high heat, chemicals or other additives. The Hydro-Dehazer's huge rotor mixes moisture-laden oil with free air until the moisture is absorbed, rises to the top, and is discharged.

Produces bright, haze-free furnace oil and diesel fuel at 400 B.P.H. Economy has been proven in installations which show that Hendrick has the most efficient method—and the lowest operating cost—of all dehazers.







Hendrick will be glad to arrange a free demonstration. For details, mail this coupon today.

HENDRICK MANUFACTURING COMPANY
36 Dundaff Street, Carbondale, Pennsylvania

Gentlemen: I am interested in learning more about the new Hendrick Hydro-Dehazer.

☐ Please arrange demonstration of the Dehazer Pilot Model.

☐ Please send technical data.

NAME_____ TITLE_____

COMPANY_____

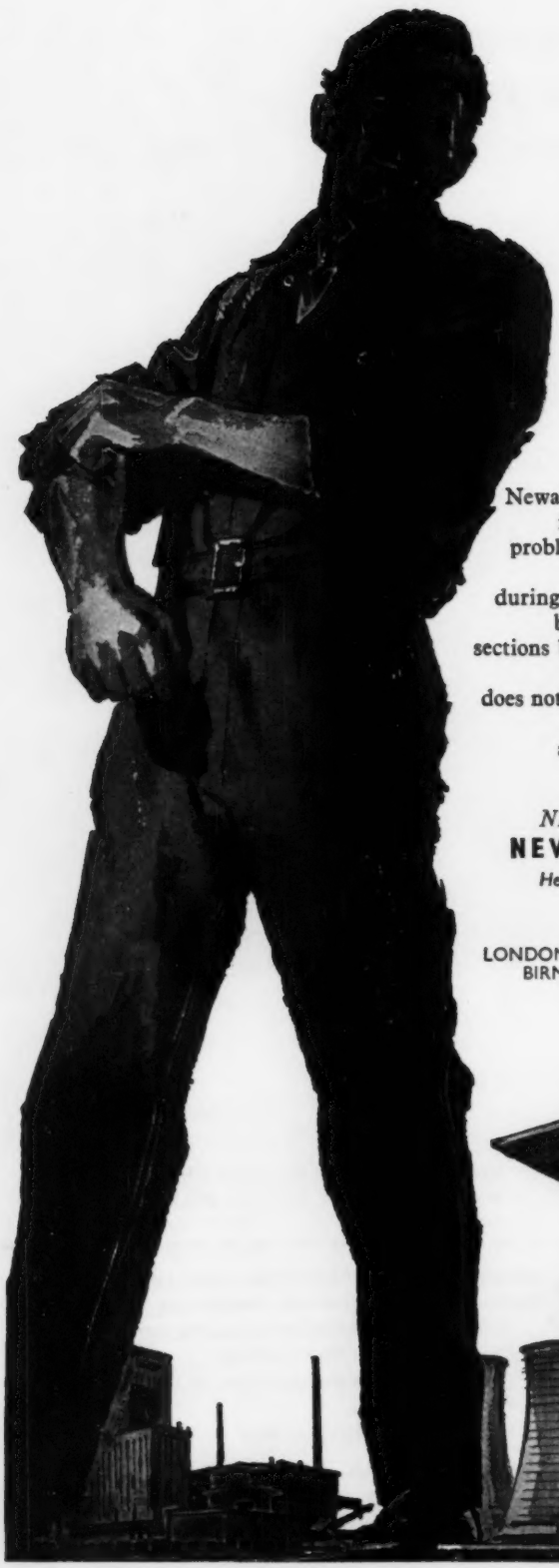
STREET ADDRESS_____

CITY_____ STATE_____

Hendrick
Manufacturing Company
Carbondale, Pennsylvania

PERFORATED METAL • PERFORATED METAL SCREENS • WEDGE-SLOT AND HENDRICK WEDGE WIRE SCREENS • ARCHITECTURAL GRILLES MITCO OPEN STEEL FLOORING • SHUR-SITE TREADS • ARMORGRIDS HENDRICK HYDRO DEHAZER • DISTILLATION COLUMN INTERNALS FLUIDIZED BED PERFORATED PLATES AND GRIDS

For more data on advertised products, use Readers' Service Cards, last page.



give NEWTHERM your toughest insulation assignment

Newalls (Reg'd Brand) NEWTHERM Calcium Silicate insulation is the finest answer yet to many of industry's heat insulation problems. *Strong and rigid,* Newtherm withstands rough handling in transit and erection, with negligible breakages even during transport to remote sites. *Exceptionally light,* Newtherm can be applied in difficult situations with ease — even the largest sections being manageable in one hand. *Moisture resistant,* Newtherm retains much of its strength even when immersed in water, does not deform, and quickly dries, leaving its strength and thermal efficiency unimpaired. *Easily applied,* Newtherm offers a smooth surface and straight edges for speedy fitting, and is available in many standard sizes for immediate application.

NEWTHERM Calcium Silicate is manufactured solely by

NEWALLS INSULATION COMPANY LIMITED

Head Office : **WASHINGTON, CO. DURHAM, ENGLAND**

A member of the TURNER & NEWALL ORGANISATION

Offices and Depots at :

LONDON, GLASGOW, MANCHESTER, NEWCASTLE UPON TYNE, BIRMINGHAM, BELFAST, DUBLIN, BRISTOL and CARDIFF.

Agents and vendors in most markets abroad.

GREATER SELECTION

...another plus value
from **TUBE TURNS**

LIGHT WEIGHT FITTINGS FOR LOWER-COST PIPING!

You can use larger diameters of thin wall steel piping to get greater flow area, lighter weight, lower costs. Tube Turns offers the most complete line of forged light weight welding fittings for these economies. Here is just one of the many PLUS VALUES you get when you specify TUBE-TURN® products.

MORE!

MORE OF 'EM...QUICKER!

Another
PLUS VALUE
provided by your
TUBE TURNS' DISTRIBUTOR

Tube Turns' 12,000 stocked items comprise the world's broadest line of welding fittings and flanges. You can buy any of these on *one order,* from *one source*... your nearby Tube Turns' Distributor. This *wide selection and prompt delivery* simplify purchasing, assure matching of specs, reduce job delays, cut costs. Outstanding *availability service* is just one of the many PLUS VALUES you get when you specify and buy top-quality TUBE-TURN* products. Others are shown here.

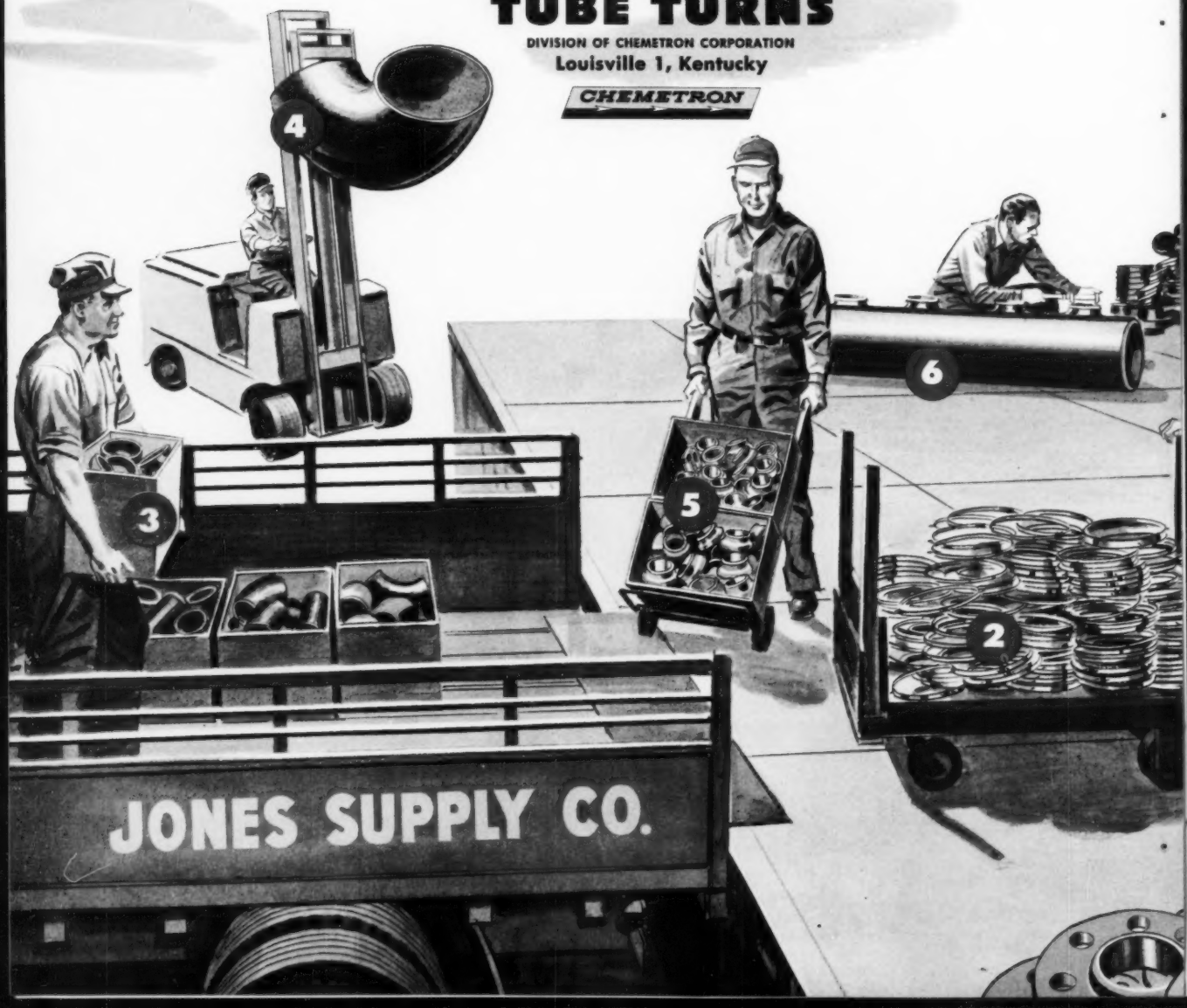
DISTRIBUTOR

The trademarks "TUBE-TURN" and "tt" are applicable only to the quality products of Tube Turns.

DISTRICT OFFICES: Atlanta • Chicago • Dallas • Denver • Detroit • Houston • Kansas City • Los Angeles • Midland • New Orleans • New York • Philadelphia • Pittsburgh • San Francisco • Seattle • Tulsa
IN CANADA: Tube Turns of Canada Limited, Ridgetown, Ontario
DISTRICT OFFICES: Edmonton • Montreal • Toronto • Vancouver

*"TUBE-TURN" and "tt" Reg. U. S. Pat. Off.

TUBE TURNS
DIVISION OF CHEMETRON CORPORATION
Louisville 1, Kentucky
CHEMETRON



MAIL COUPON FOR FREE DATA
on products featured here.

TUBE TURNS
224 E. Broadway • Louisville 1, Kentucky

Please send me the following bulletins checked:

- ☐ Taper Face Flanges
- ☐ Knock-off Spacer Rings
- ☐ Light Weight Fittings
- ☐ Scale-free Couplings
- ☐ Pipe Line Specials
- ☐ Wrought Iron Fittings
- ☐ Alloy Fittings

Company Name _____

Company Address _____

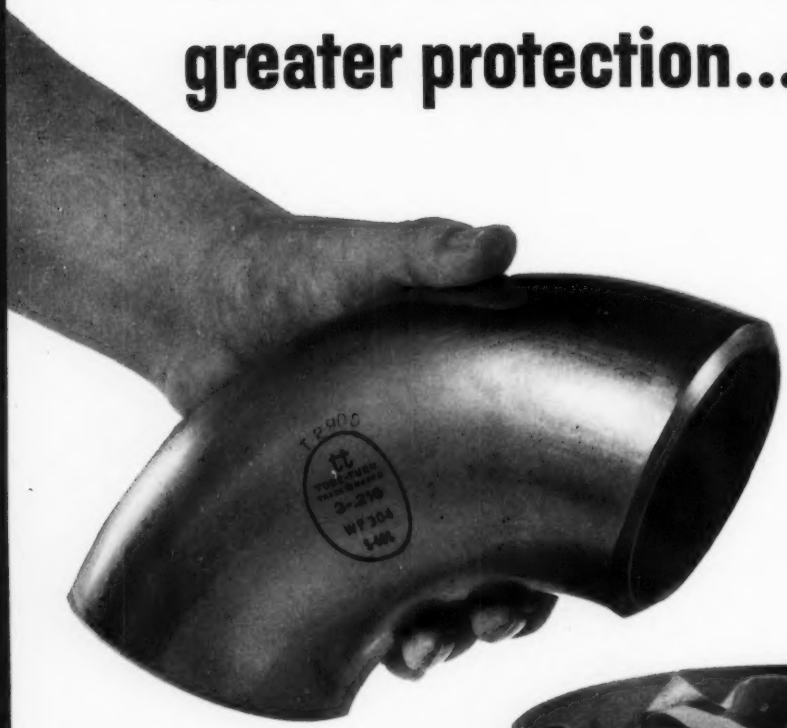
City _____ *Zone* ____ *State* _____

Your Name _____

Position _____

ANOTHER tt® PLUS

greater protection...convenience

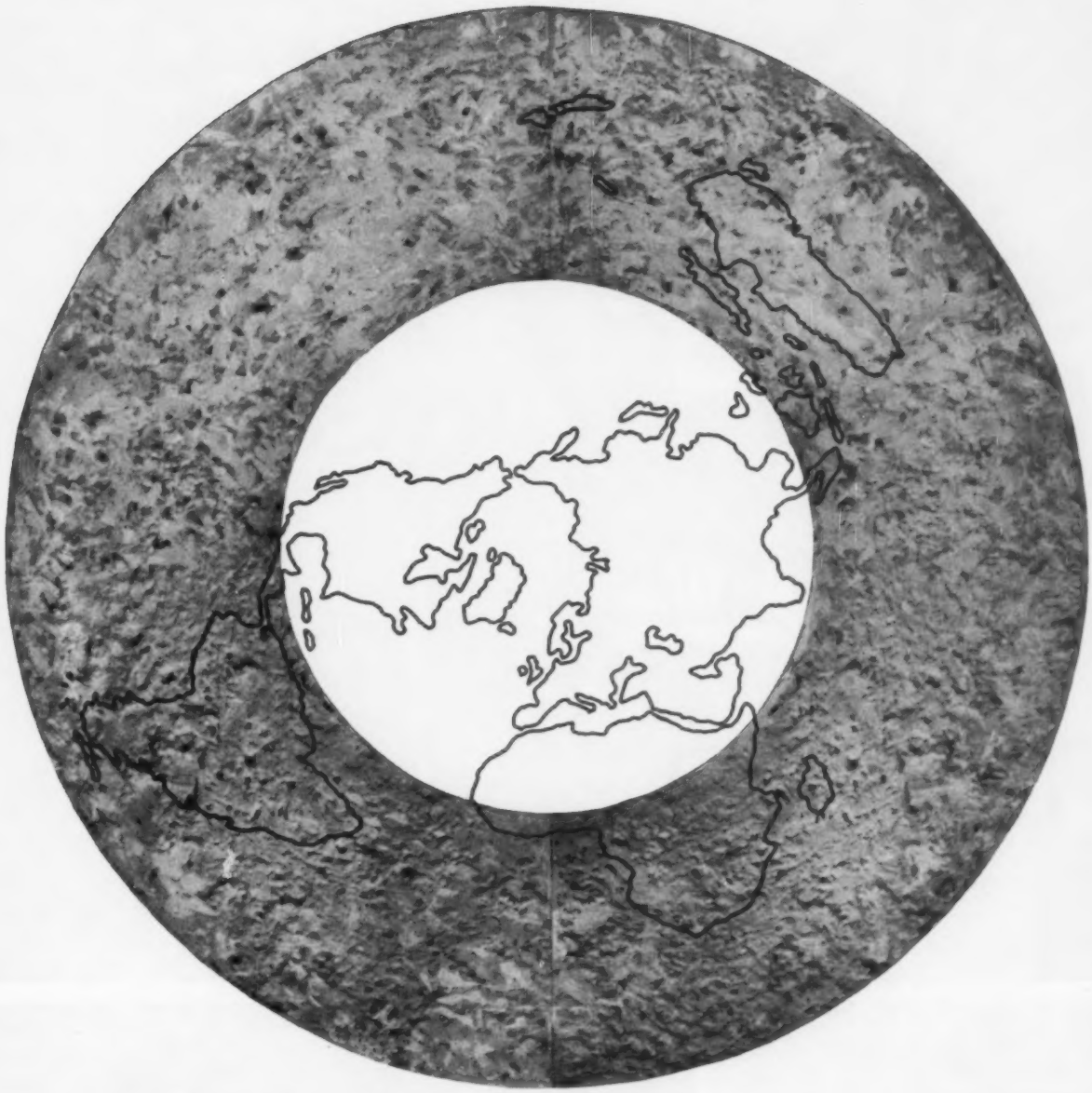


TUBE-TURN® ALLOY WELDING FITTINGS AND FLANGES ARE INDIVIDUALLY PACKAGED

Here is an important new safeguard... and new convenience... for users of stainless steel, aluminum and other non-ferrous alloy piping. Tube Turns is now individually packaging all its fittings and flanges of these materials. Rugged containers protect each fitting from inspection to job site. And, fully marked, these containers simplify storage and identification.

Here is another PLUS VALUE you get when you specify TUBE-TURN® products and buy from your nearby Tube Turns' Distributor.

MORE!



made the world over

—and to the same specification

Caposite amosite asbestos is manufactured under supervision to the same uniform specification in all these countries.

Great Britain	by The Cape Asbestos Company Ltd
Canada	by Caposite Insulations Ltd
South Africa	by Cape Asbestos Insulations (Pty) Ltd
Australia	by James Hardie & Company Ltd
France (as 'Isolamiante')	by Isolamiante SA
Italy	by Capamianto SpA
Holland	by J. de Boer & Company
Spain	by Messrs. Eduardo Rosa
Argentina	by Montisol Argentina. SRL
Japan	by Nippon Asbestos Company

Amosite asbestos insulation is also manufactured in U.S.A. under the name of 'Unibestos' by Union Asbestos Rubber Company.

CAPOSITE
regd.
AMOSITE ASBESTOS INSULATION

CAPE

THE **Cape Asbestos** COMPANY LTD 114 & 116 Park St. London W1. Grosvenor 6022

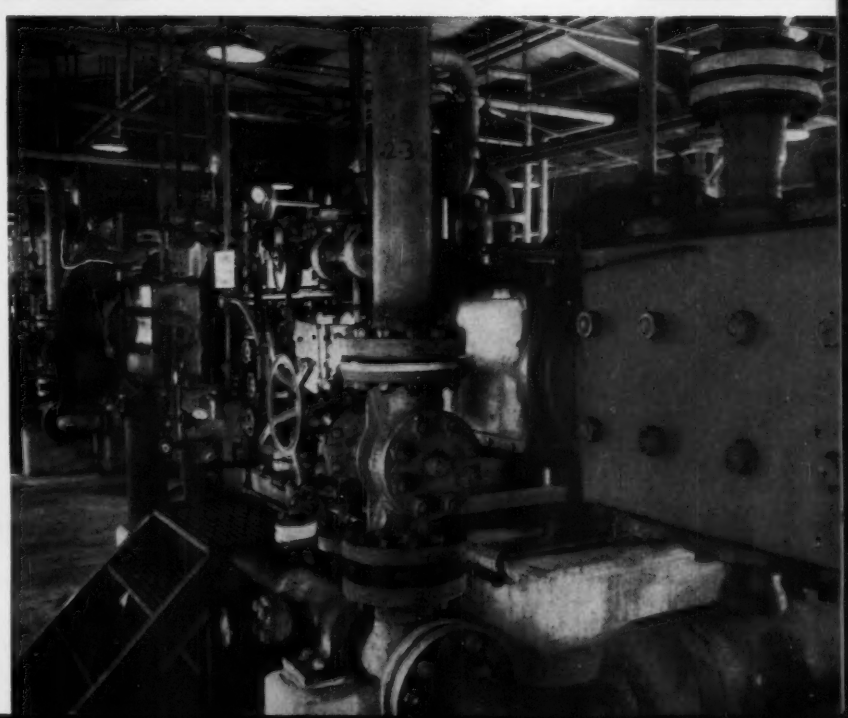
Enquiries to: Cape Asbestos (Canada) Limited, 200 Bloor Street East, Toronto, Ontario. North American Asbestos Corporation, Board of Trade Building, Chicago 4, Illinois. Capamianto SpA via Sant' Antonino 57, Turin, Italy.

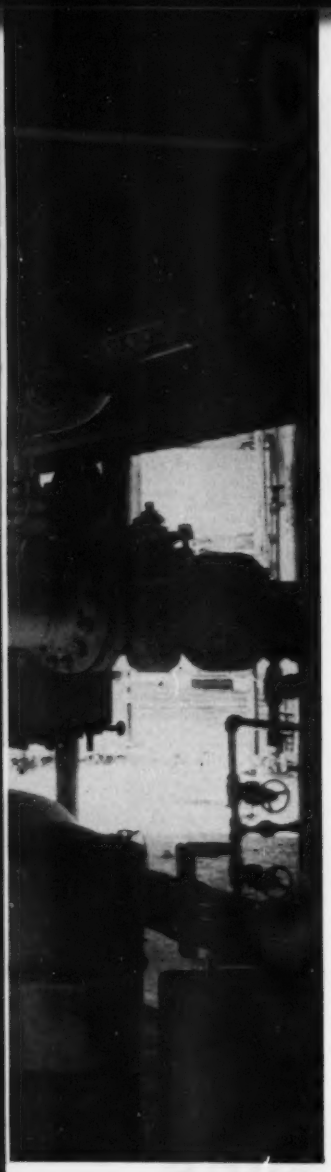
TA.3512

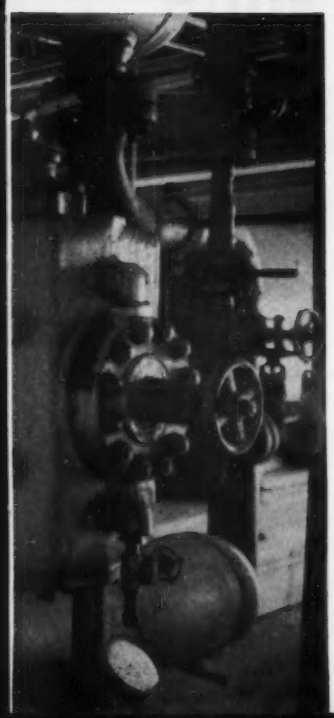
For more data on advertised products, use Readers' Service Cards, last page.

A 1200 hp Cooper-Bessemer Type FM Compressor which transfers make-up hydrogen to the hydrodesulfurization plants.

600 hp Cooper-Bessemer Type FM Compressors recycling hydrogen within the naphtha (gasoline) hydrodesulfurization plant.







How 7 Cooper-Bessemer Compressors put 700 psi behind sulphur removal

Hydrodesulfurization at Wood River... Shell Oil Company's largest refinery... removes sulphur from 25,000 barrels of high octane gasoline and 25,000 barrels of fuel oil daily. In this process, the job of compressing hydrogen to 700 psi for removal of sulphur belongs to six Cooper-Bessemer Type FM motor-driven compressors. And a seventh FM unit compresses the hydrogen sulphide product to 100 psig for the manufacture of free sulphur... an output of 100 tons per day.

These 7 Cooper-Bessemer Compressors operate 24 hours per day, 7 days per week. Two units are 1200 hp; four are 600 hp and one is 400 hp... all running at 450 rpm.

Cooper-Bessemer engineers will gladly help *you* plan compression and power facilities for refining and petrochemical processing. Write for a copy of "Cooper-Bessemer Equipment for Refineries."

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Pittsburgh Chicago • Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans • Shreveport • Houston Greggton • Dallas • Odessa • Pampa • Casper • Seattle • San Francisco • Los Angeles

SUBSIDIARIES: Cooper-Bessemer of Canada, Ltd.... Edmonton • Calgary • Toronto Halifax • Stratford

C-B Southern, Inc.... Houston

Cooper-Bessemer International Corp.... New York • Caracas • Anaco

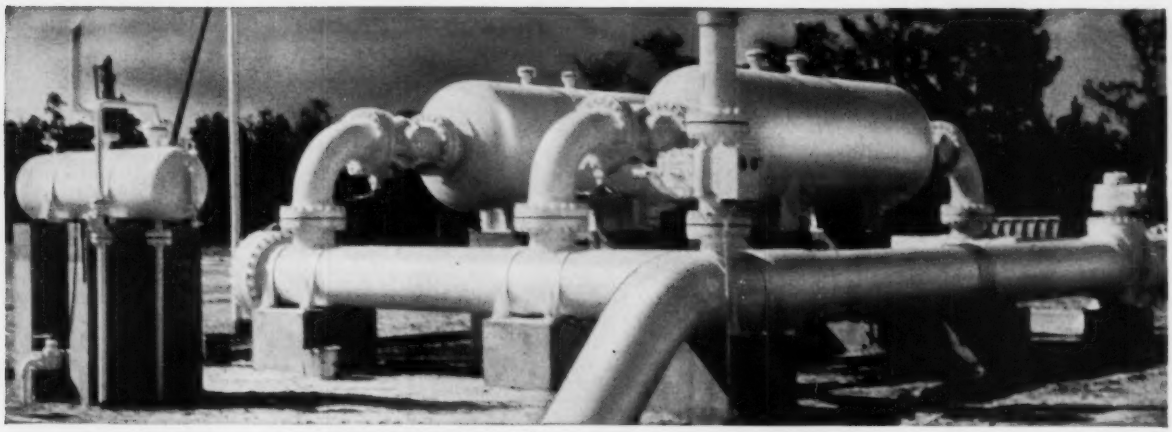
Cooper-Bessemer, S.A.... Chur, Switzerland • The Hague, Netherlands • Mexico City

The Rotor Tool Company... Cleveland

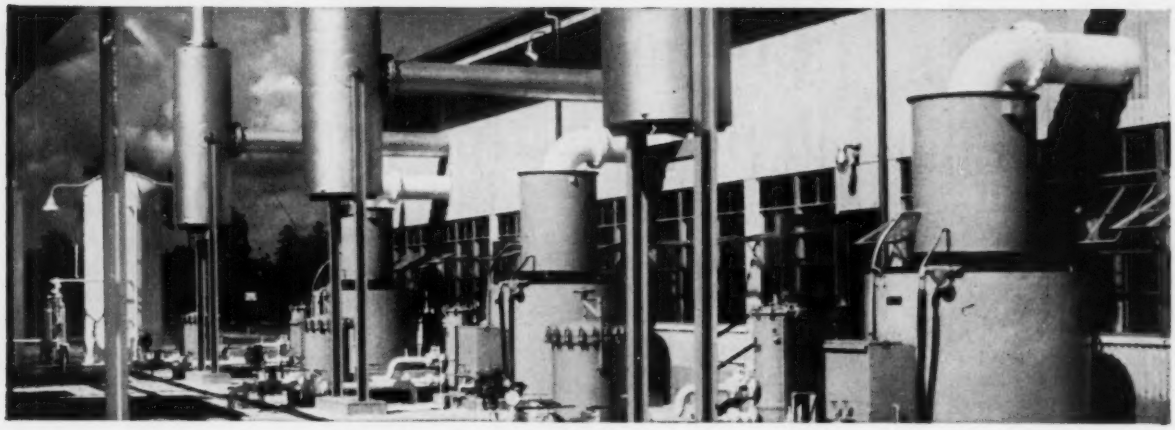
Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS • DIESEL • GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL, ENGINE OR MOTOR DRIVEN



AAF cleans gas...



...as well as air on new Texas-Florida pipeline

● On Houston Corporation's new Texas-to-Florida pipeline, both intake air for compressor engines AND gas being pumped are cleaned by AAF!

The pipeline – operated by Houston Texas Gas and Oil Corporation – is bringing natural gas to Florida for the first time. And it's *clean* gas, too, after it passes through AAF horizontal gas cleaners (top photo). These oil-bath cleaners (installed at all compressor stations on the line) remove liquids, contaminants, and foreign matter from the gas before it goes into the compressors for transmission.

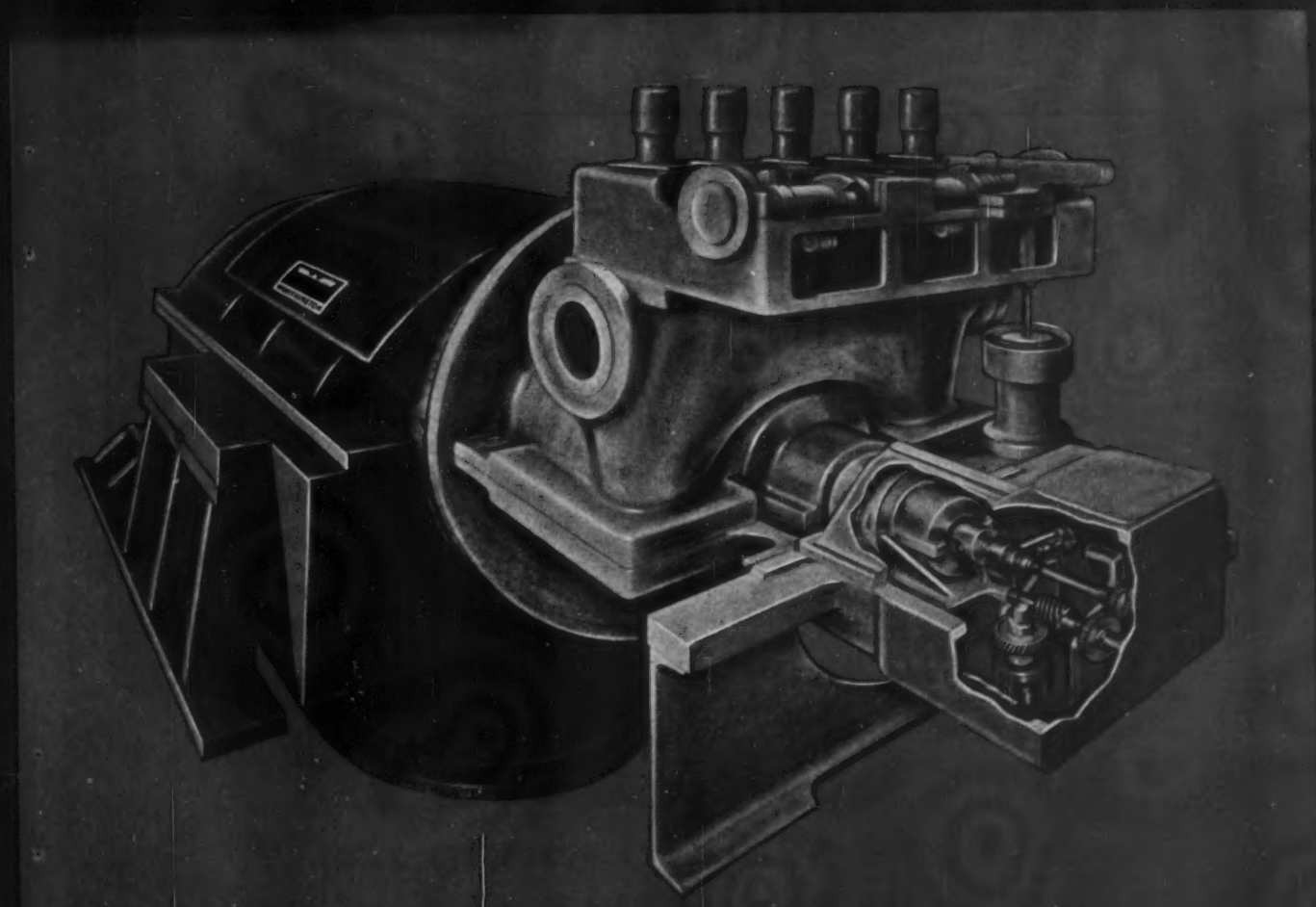
Smoother engine performance is assured by AAF Cycoil Kool-Airs (bottom photo). These combination cleaner-coolers – which also operate on the oil-bath principle – condition intake air before it goes into the engine.

American Air Filter can help with *your* air- or gas-cleaning problem – wherever it might be in the petroleum or petro-chemical industry. You can get complete information from your nearest AAF representative, or by writing Mr. Robert Moore, American Air Filter Company, Inc., 452 Central Avenue, Louisville, Kentucky.

AAF **American Air Filter**

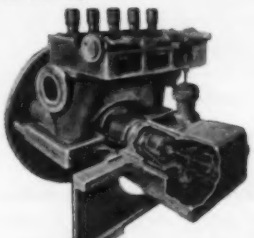
BETTER AIR IS OUR BUSINESS

For more data on advertised products, use Readers' Service Cards, last page.

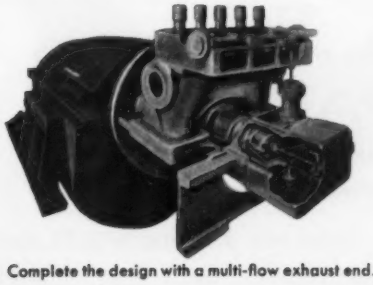


HOW WE ASSURE RELIABILITY IN A NEW DESIGN

1. Use an existing high-speed bearing case and a high capacity thrust bearing.



2. Add a high-pressure steam end of proved design with cam operated automatic nozzle control valves.



3. Complete the design with a multi-flow exhaust end.

HOW TO BUILD THE WORLD'S FASTEST 10,000 HP TURBINE

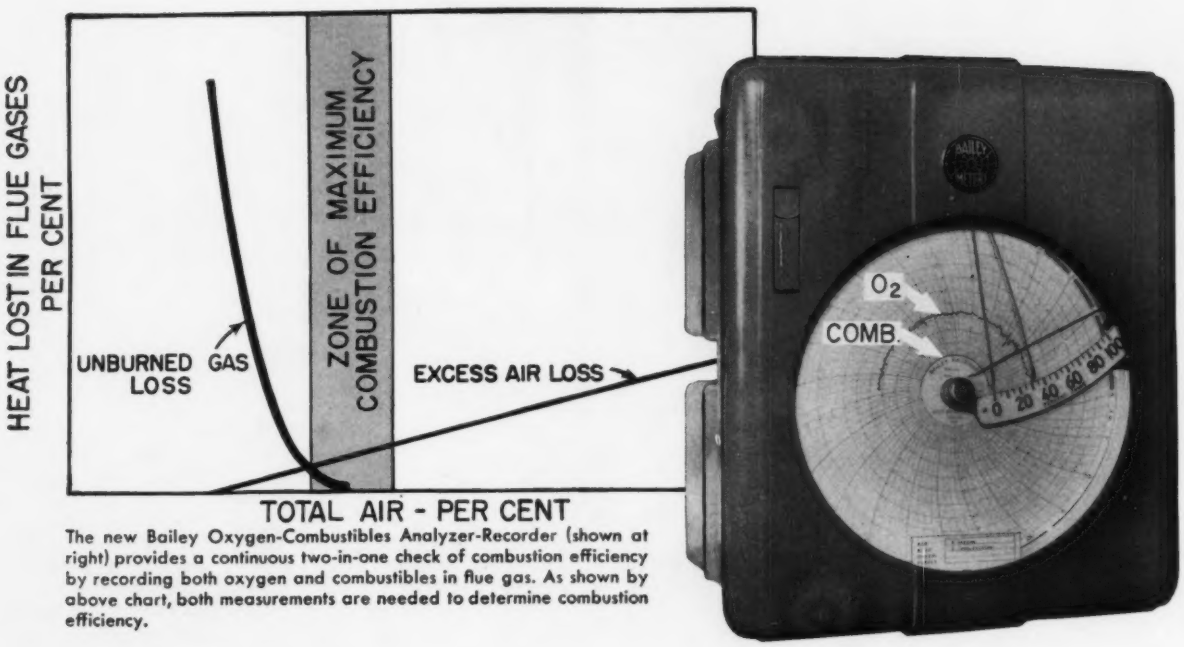
You can order this trail-blazing 15,000 rpm centrifugal compressor-drive turbine today with complete confidence because it makes use of components of proved reliability

Progress without sacrificing reliability is the goal of Worthington's Steam Turbine Division. How Worthington's creative engineering and advanced planning works to your advantage is illustrated by the steps taken in the continuing development of turbines of increasingly higher speeds:

1. Wherever possible use existing components proved reliable by years of operation.
2. Modify designs already in use in other high speed applications.
3. Thoroughly test these modifications to prove their reliability before field application.

Such advances in the turbine art bring new economies to high-speed, high-horsepower compressor drive applications. For information, call your nearest Worthington district office or write Worthington Corporation, Section 48-9, Wellsville, New York.

WORTHINGTON



The new Bailey Oxygen-Combustibles Analyzer-Recorder (shown at right) provides a continuous two-in-one check of combustion efficiency by recording both oxygen and combustibles in flue gas. As shown by above chart, both measurements are needed to determine combustion efficiency.

BAILEY announces . . .
New 2 in 1 way to measure Heater Combustion Efficiency

The new Bailey Oxygen-Combustibles Analyzer-Recorder gives you a continuing double check on combustion economy. It's fast response measures and records:

1. Excess air—regardless of the fuel or combinations of fuels being burned.

2. The mixing efficiency of your fuel-burning equipment—by indicating the amount of combustibles in your flue gas, resulting from incomplete mixing of fuel and air.

Combustion efficiency depends upon fuel-air ratio. Too much fuel can be even more costly than too much air. And because of the interdependence of these two factors, no control that measures only one of them can give you complete protection.

Now, for the first time, you can check *both* with a *single* fast acting instrument, using the new Bailey Oxygen-Combustibles Analyzer-Recorder for industrial furnaces, kilns, heaters and boilers.

Fuel economy improves as excess air is reduced —until unburned fuel begins to show up in the flue gas. When this happens, combustion efficiency drops off sharply if there are further decreases in the air-fuel ratio. That's why combustion gases must be analyzed for *both* oxygen and combustibles to get a true indication of efficiency—and that is why Bailey coordinates both measurements on the same chart, to show when excess air may be reduced safely without danger of greater losses from unburned gases.

The Bailey Oxygen-Combustibles Analyzer is an approved combustion safeguard.

Ask your local Bailey engineer for suggestions on application. Equipment details in Product Specifications E65-1 and E12-5. CP107-1

Chemical and petroleum division

BAILEY METER COMPANY

1043 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

The warning that comes too late!

WHEN THIS HAPPENS, it's already too late. Lubricant has leaked out, and dirt or grit have probably damaged your bearings and shaft.

You can avoid sealing problems by using Johns-Manville Clipper Seals because you can count on them to outlast time between regular overhauls. They seal efficiently . . . give better protection. That's why Clipper Seals are selected as original equipment by many automotive, marine and aviation manufacturers.

JOHNS-MANVILLE PRODUCES a wide range of sizes and lip designs—including Split Clipper Seals for quick, temporary replacement – in compounds that will resist every heat, speed or corrosive condition. It is smart maintenance practice to use Clipper Seals, and to keep on hand a small replacement stock of the sizes and designs you need regularly.

Let your J-M Distributor help you select the Clipper Seals that are compounded to meet your exact sealing requirements. Or write to Johns-Manville, Box 14, New York 16, N. Y. In Canada: Port Credit, Ontario.

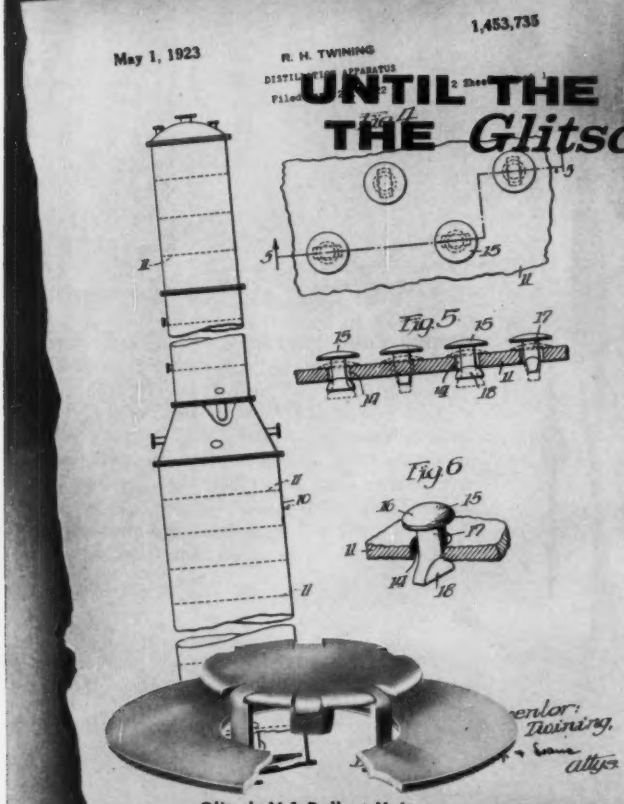
JOHNS-MANVILLE
CLIPPER SEALS

JOHNS MANVILLE JM PRODUCTS

For more data on advertised products, use Readers' Service Cards, last page.

Not since 1923

when an early patent was granted covering a valve type tray—has there been any significant change or improvement in this type of tray, other than physical shape and dimensions . . .



Glitsch V-1 Ballast Unit

UNTIL THE DEVELOPMENT OF THE *Glitsch* BALLAST TRAY

. . . a two-stage vapor discharge unit that is:

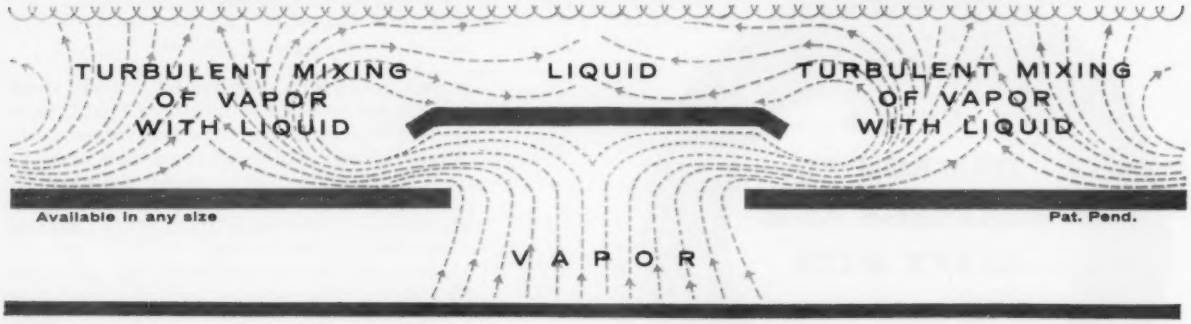
- ★ Low in cost
- ★ Low in maintenance
- ★ High in capacity
- ★ High in efficiency
- ★ High in turndown ratio

The Glitsch V-1 Ballast Unit has a single moving element with a two-stage action. The valve element positions itself initially for low to medium vapor rates and is then free to travel vertically to provide an increased orifice for very high vapor rates.

The high efficiency obtained by the Glitsch V-1 Ballast Tray is a result of the centripetal "fantail" mixing of the vapor and liquid. The vapor discharge orifice of the element is so shaped that the vena contracta at the vapor-liquid interface is amplified by the centripetal force of the vapor, resulting in extreme turbulence, greater interfacial area, and more thorough mixing of the vapor with the liquid.

For additional information on the V-1 Ballast Tray, ask your Glitsch representative for Bulletin #160. Offices in principal cities.

VAPOR-LIQUID ACTION OF THE GLITSCH V-1 BALLAST UNITS



Fritz W. Glitsch & Sons, Inc.

GENERAL OFFICES: 4900 Singleton Blvd. • P. O. Box 6227 • Dallas, Texas, U.S.A.

PLANTS: Dallas, Texas, U.S.A. • Fritz W. Glitsch & Sons (Canada) Ltd., Uxbridge, Ontario, Canada • Glitsch-Monterrey, S.A., Monterrey, N. L., Mexico.

SALES OFFICES: New York • Cleveland • Tulsa • Houston • Los Angeles • Baton Rouge Charleston, W. Va. • Sarnia, Ontario

Glitsch "SINGLE ENGINEERING RESPONSIBILITY"

Manufacturers of Superior Fractionating Trays Since 1937

For more data on advertised products, use Readers' Service Cards, last page.

M·A·N

The following are some of the products we design and manufacture:

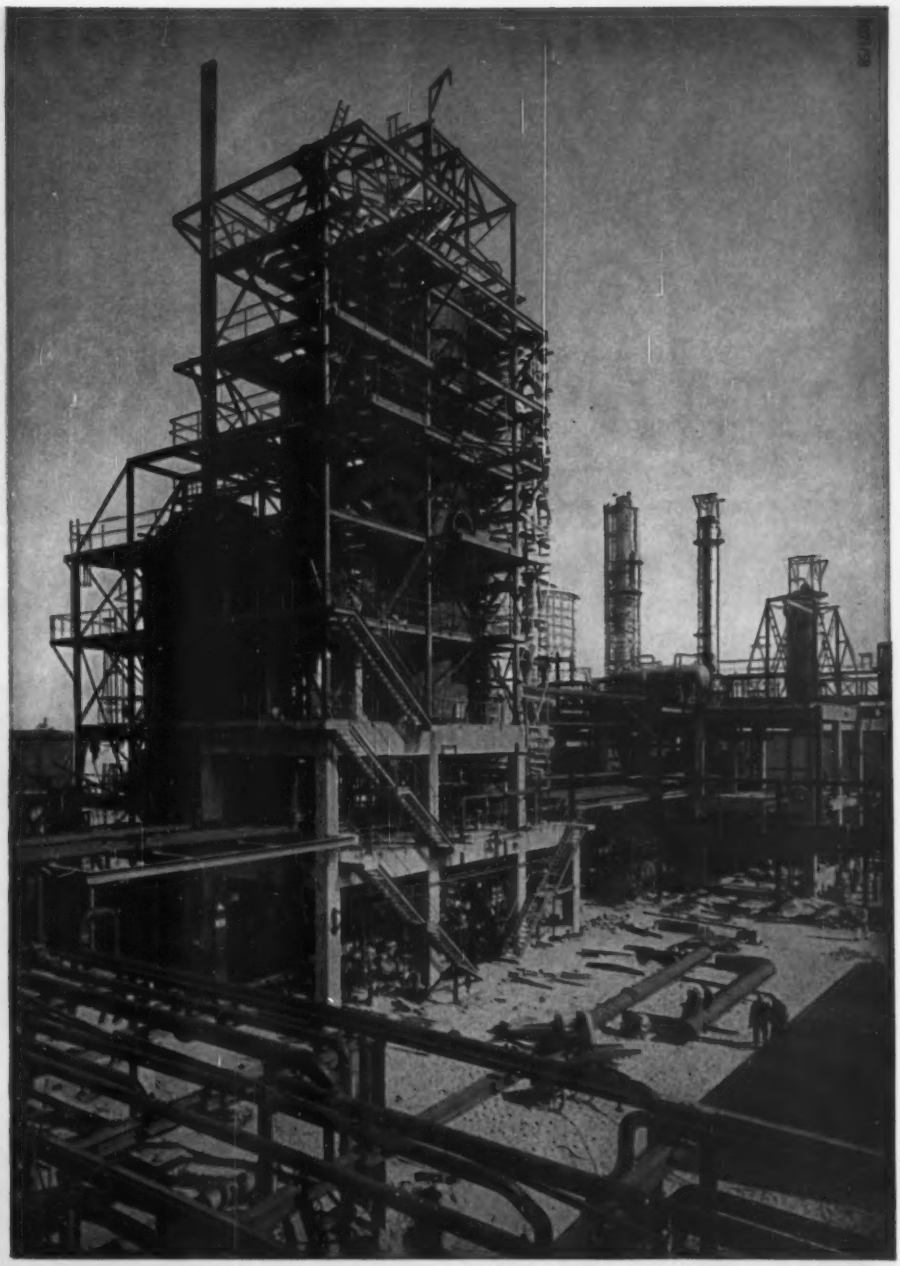
STEAM BOILERS

STEAM POWER STATIONS

TURBINES

DIESEL ENGINES

GAS ENGINES



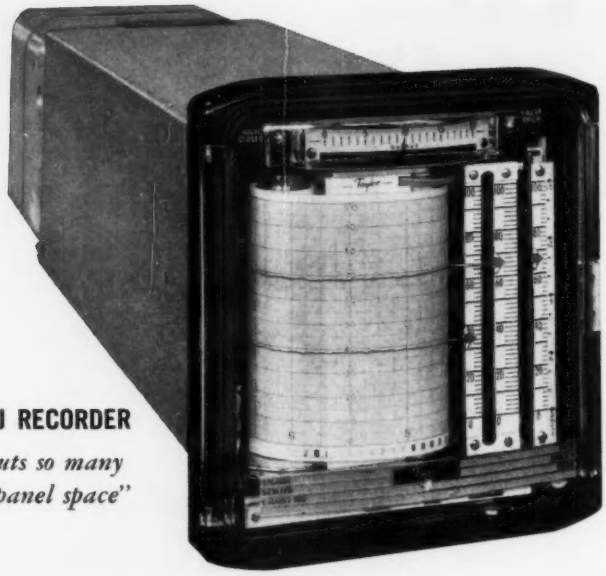
Responsible for process and engineering were:
N. V. de Bataafsche Petroleum Mij., The Hague
and Lummus Nederland N. V., The Hague.
Responsible for purchasing was:
Edeleanu GmbH, Frankfurt.

We recently supplied and installed all apparatuses and structural steelwork required for the

CAT CRACKER AND GAS RECOVERY PLANT
DEUTSCHE SHELL AG
HOHE SCHAAR REFINERY, HAMBURG

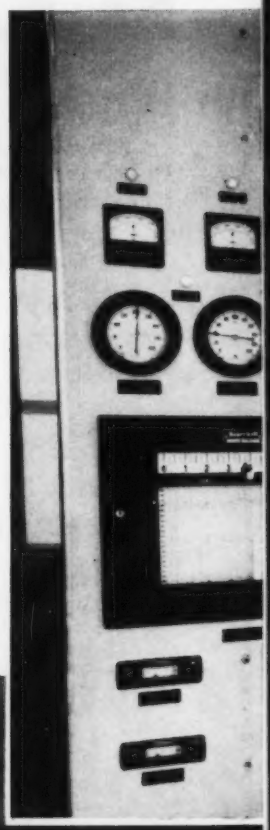
MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) · REPRESENTATIVES IN ALL COUNTRIES

For more data on advertised products, use Readers' Service Cards, last page.



TAYLOR TRANSCOPE 90J RECORDER

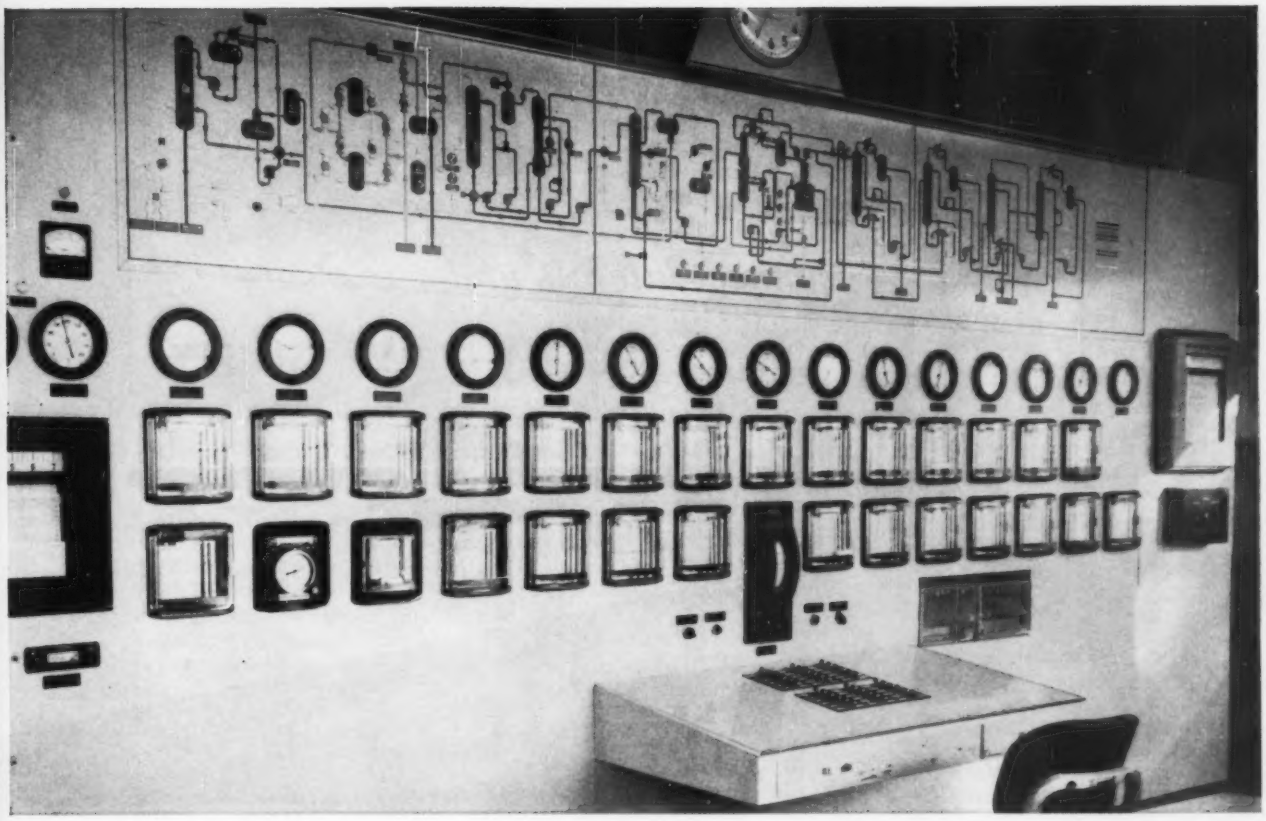
"No other recorder puts so many features in so little panel space"



New natural gasoline plant, in the Laverne field of Harper County, Oklahoma, operated by Sun Oil Company.

Taylor Instruments

For more data on advertised products, use Readers' Service Cards, last page.



SUN-OPERATED NATURAL GAS PLANT FULLY AUTOMATED BY TAYLOR

Features most modern semi-graphic panel and TRANSCOPE® instrumentation!

Located in the Laverne field of Harper County, Oklahoma, this Sun Oil Company-operated natural gas processing plant was designed to process 100 million cubic feet of gas per day, for later expansion to 150 million cubic feet. Sun Oil is the operator for itself and eleven other companies. It was built by the J. F. Pritchard Company, of Kansas City, Mo., and is the first of its type in the country to use gas-fired turbines for generating power and process heat.

Taylor flow and temperature transmitters, recorders and controllers are used throughout the highly automated Laverne plant. On the panel shown above, note particularly that the 4" TRANSCOPE (90J) Recorders are extremely compatible with the semi-graphic panel. They give unconfused readability because chart record, pen and set-point are side-by-side. They also assure unprecedented accuracy of records because of servo-operated pen mechanism which provides 150 times greater power than conventional systems.

Sun Oil Company engineers are well pleased with the operation of their Taylor control systems. We are proud to have supplied the instrumentation for one of the world's most modern gasoline plants.

Your Taylor Field Engineer will be glad to demonstrate the many revolutionary features of the TRANSCOPE Recorder. Call him, or write for **Bulletin 98286.** Taylor Instrument Companies, Rochester, New York, or Toronto, Ontario.

MEAN ACCURACY FIRST

For more data on advertised products, use Readers' Service Cards, last page.

connect laterals under pressure

QUICKLY SAFELY SIMPLY

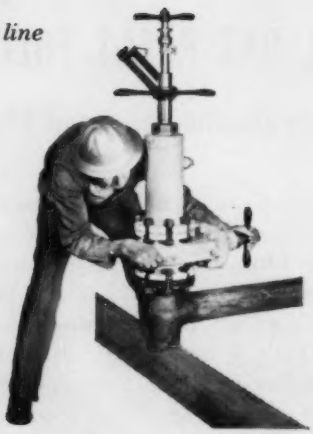
with the

MUELLER® NO-BLO® METHOD

■ *Only these simple operations are needed to quickly connect a 4" lateral under pressure to a steel line with a No-Blo Flanged Tee.*

1. WELD

Remove cap and loosen plug. Weld Flanged Tee to line. Weld lateral to Flanged Tee. Complete lateral to first shut-off. Test welds with soapsuds. Bolt gate valve—hand tight—to fitting and open valve.



2. ALIGN

Attach alignment tool and completion plug to shaft of H-17235 Stopping Machine. Bolt machine—hand tight—to gate valve. Align machine and valve with fitting. Insert plug into fitting and tighten bolts. Mark position of machine on valve. Remove completion plug and machine.

3. ASSEMBLE

Bolt adapter to CH-6 Drilling Machine. Advance boring bar with rapid feed hand crank. Attach cutter arbor, pilot drill and shell cutter to boring bar. Retract boring bar to rearmost position. Bolt machine to the open gate valve.

Write for complete information and specifications.

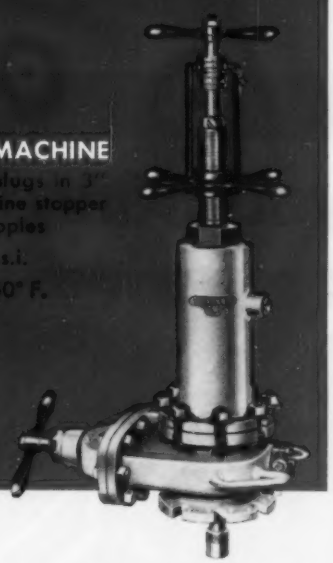
H-17235 STOPPING MACHINE

. . . inserts and extracts plugs in 3" and 4" flanged tees, line stopper fittings and drilling nipples

. . . for pressures to 100 p.s.i.

. . . for temperatures to 250° F.

. . . hand operated



These machines and fittings are just a small part of Mueller's complete system of No-Blo products—products especially designed for working with fluids under pressure.

■ Large lateral line connections can be made to existing lines in just a few minutes when your crew is equipped with a Mueller CH-6 Drilling Machine and H-17235 Stopping Machine. These compact machines are ideal for connecting 3" and 4" lines under pressure. Automatic operation of the "CH-6" simplifies the operator's job, assures safe operation and saves time.

CH-6 DRILLING MACHINE

. . . makes cuts from 2" to 6"

. . . shell cutters designed for cutting any type pipe

. . . up to 24" boring bar travel

. . . for pressures to 1440 p.s.i. at 100° F.

. . . for temperatures to 500° F. at 1250 p.s.i.

. . . features automatic operation without supervision

. . . automatic feed disengagement and over-travel protection

. . . direct reading tool position and feed indicators

. . . telescopic design for handling ease

. . . self-adjusting boring bar packing

. . . for power operation with air or gasoline engine drive unit

. . . may also be operated by hand

4. CUT

Test set-up for pressure tightness. Advance boring bar until pilot drill almost contacts line. Set amount of cut needed and engage automatic feed. Mount air motor on machine and open throttle. ("CH-6" will automatically make cut and disengage feed without supervision.) Lateral now in operation. Retract boring bar to rearmost position. Close gate valve and remove machine.

5. PLUG

Fasten inserting tool and completion plug to shaft of "H-17235." Bolt machine to gate valve in same position as marked. Open gate valve and insert plug solidly into top of fitting. Test tightness of plug with bypass valve. Release plug and remove machine and gate valve.

6. CAP

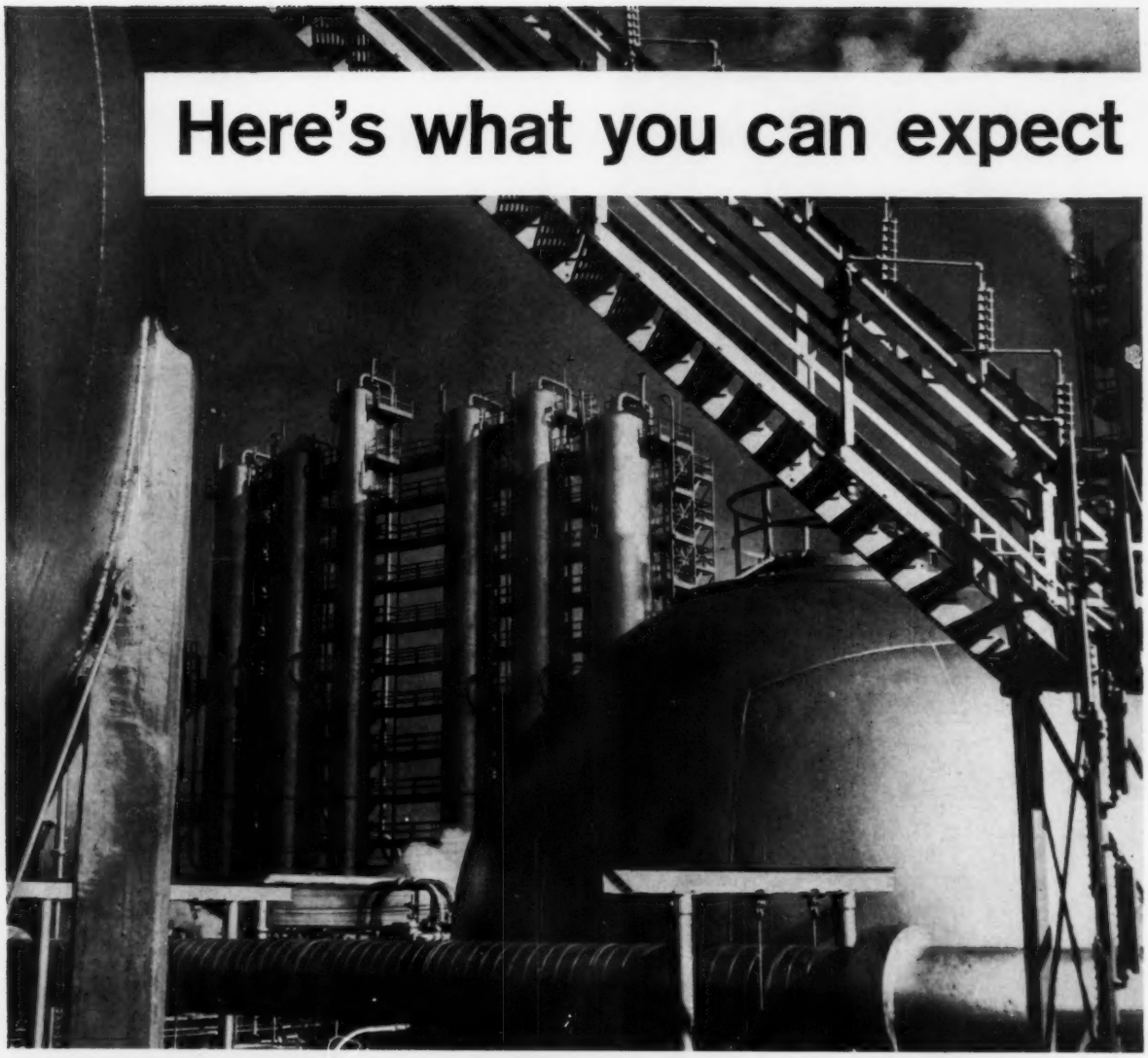
Position gasket on flange of fitting. Bolt completion cap firmly in place. Test entire set-up with soapsuds. Connection now completed and ready for backfilling.

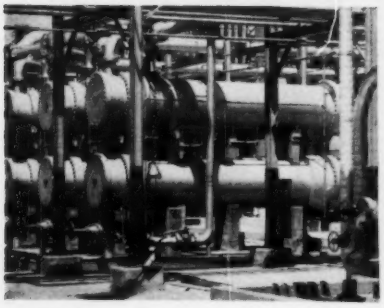
MUELLER CO.,

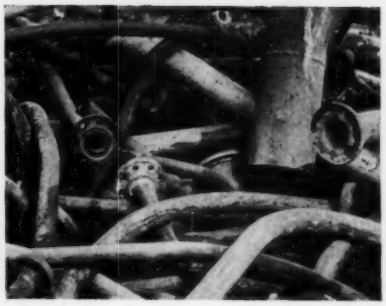
DECATUR, ILL.

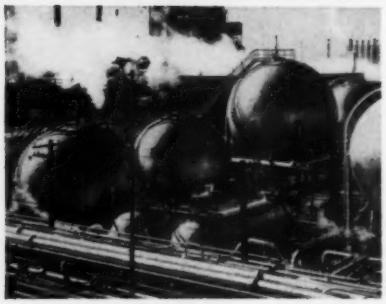
Factories at: Decatur, Chattanooga, Los Angeles;
In Canada: Mueller, Limited, Sarnia, Ontario.

Here's what you can expect









RESULTS LIKE THESE:

Typical case histories tell the story of Oakite ECP's at work in various refineries. They helped:

- **cut 3½ days, $2,250 from previous absorber turnaround time; knocked 5 days, $3,300 from reformer tower turnaround; put fouled catalytic reformer furnace back on-stream in 2 days.**
- **reduced tube bundle cleaning costs 70%; saved 8-year-old tube bundles from scrap heap.**
- **cut parts salvage operation from 22 hours to 1½ hours per batch.**
- **stripped paint from tank exterior in just a few hours; cleaned asphalt storage tank interior in 1½ days.**

Ask the Oakite man to give you complete information, or send for these valuable bulletins. Write Oakite Products, Inc., 48 Rector Street, New York 6, N. Y.

For more data on advertised products, use Readers' Service Cards, last page.

from an Oakite ECP

engineered cleaning program

Savings in turnaround time, in money, man-hours, and maintenance—these are some of the things you can expect from an Oakite Engineered Cleaning Program. ECP takes a scientific approach to cleaning *through chemistry*. It is tailored specifically to suit your refinery, your equipment, your soils, your throughput. ECP gives you:

DETAILED RECOMMENDATIONS

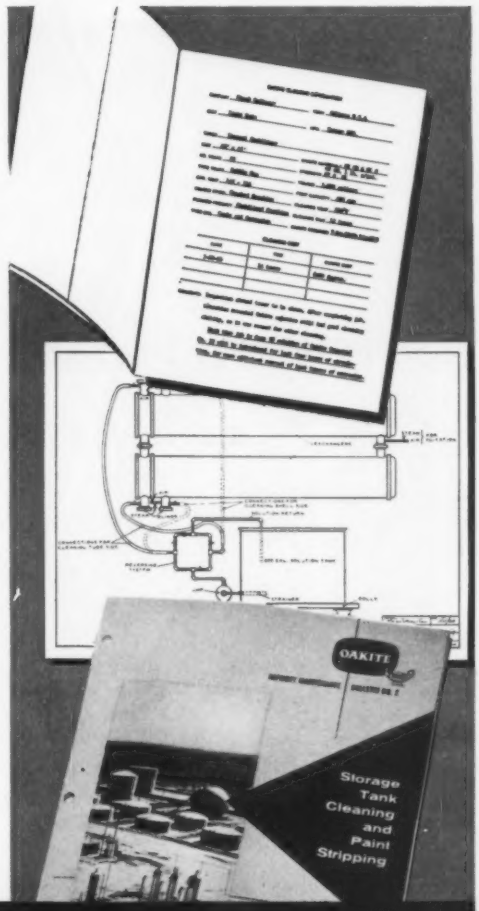
Specific cleaning recommendations—tower by tower, bundle by bundle—are outlined in a complete, written report. It includes estimated quantities of materials required, estimated off-stream time, step-by-step instructions for your crew. ECP utilizes time-saving mechanized and in-place cleaning wherever possible.

TECHNICALLY QUALIFIED AID

To implement the program, the Oakite man sticks with the job until your crew is fully oriented. He brings with him a background of practical refinery cleaning experience... coupled with materials and methods from the finest cleaning research laboratory in the country. In short, your Oakite man is expressly prepared to give you top efficiency, speed of operation *plus* low-cost end results.

ENGINEERING DRAWINGS, LITERATURE

Engineering drawings of suggested equipment and pumping hook-ups are included in the ECP. And fact-filled literature that details cleaning procedures is made available.



OAKITE®

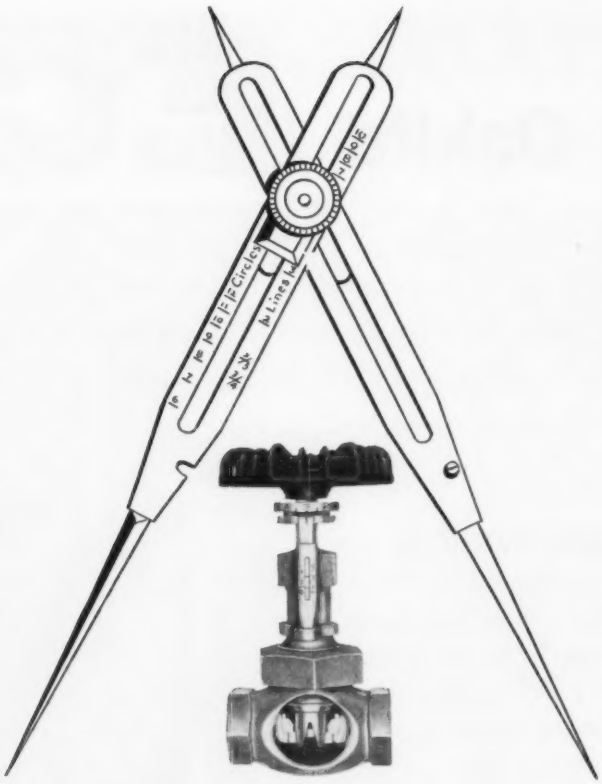
over 50 years' leadership in industrial cleaning

Est. 1909 SCIENCE

ECP

your economy key

For more data on advertised products, use Readers' Service Cards, last page.



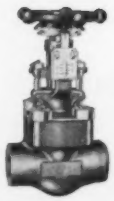
PROPORTIONER

controls flow to save for you

The V-port disc in all Hancock "Flocontrol" Valves insures proportional flow throughout the entire lift of the stem. They are valves that help you achieve uniform product quality through closer control, save steam and fuel on process work, and cut maintenance costs.

"3 in 1" valve design combines variable orifice with shut-off and micrometer dial and pointer. The valve opening can be set within 1/10 turn of the handwheel —you can duplicate all settings easily, instantly. No shut-off valve required—flow is in a straight line, with separate shut-off seating surface located away from the V-ports.

Hancock "Flocontrol" Valves are available in Bronze and Steel to meet the most demanding services. Ask your industrial supply distributor for details.



Hancock "Flocontrol" valves assure positive pinpoint control—eliminate all guesswork.

MANNING MAXWELL & MOORE INC. MM&M TRADE MARK

HI-58

HANCOCK "FLOCONTROL" VALVES

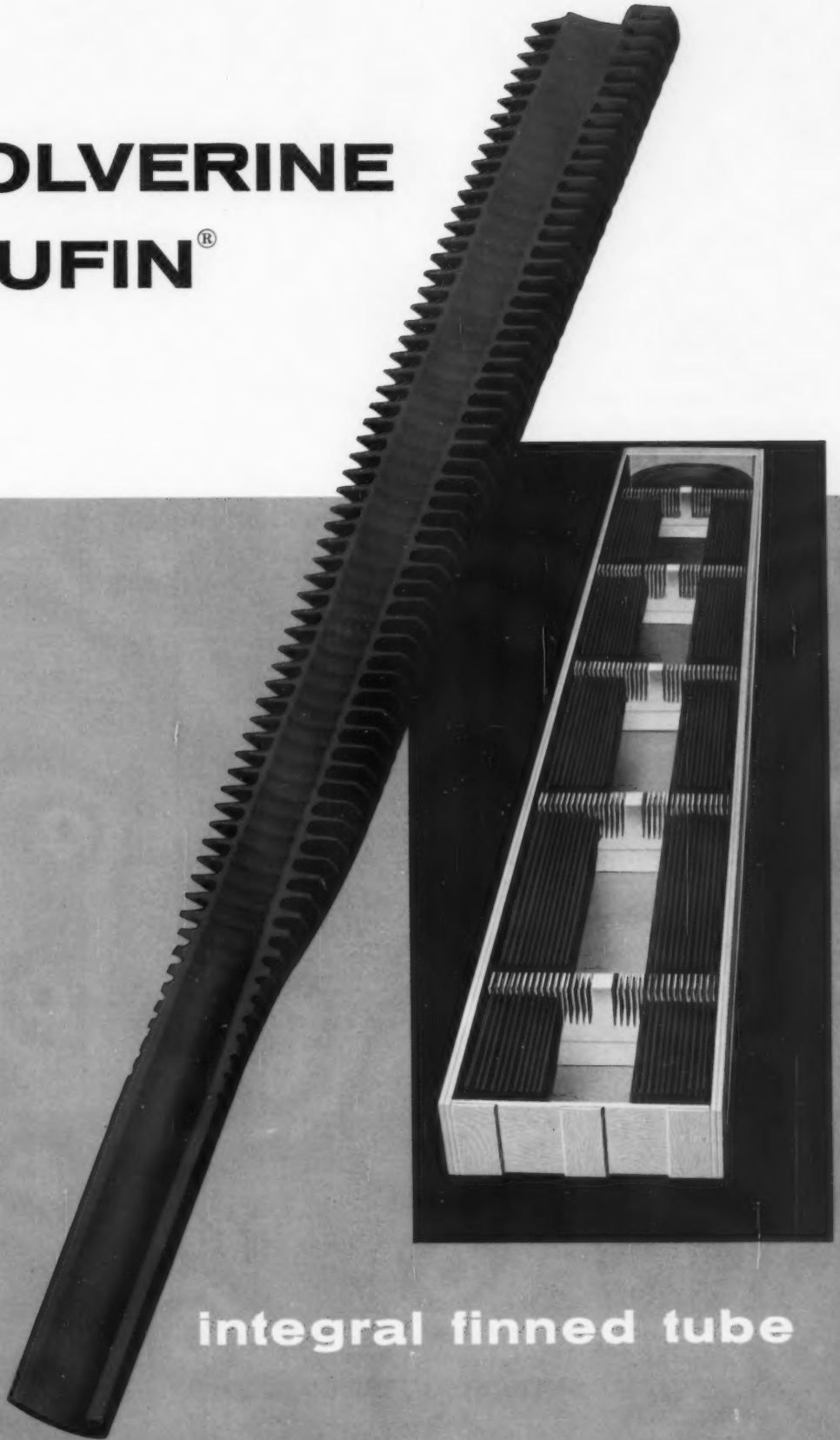
A product of

MANNING, MAXWELL & MOORE, INC.

Valve Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.

WOLVERINE TRUFIN®



the integral finned tube

when EXPERIENCE counts

—you can count on

WOLVERINE TUBE

Wolverine Tube developed integrally finned tubing (Wolverine Trufin) in 1928 and since that time has been the originator of most of the available information on finned tube technology.

Wolverine research has uncovered the most advantageous applications of Trufin and has developed the various types of integrally finned tube on the market today.

For the past several years, throughout the country's major processing and refining areas, Wolverine has conducted a series of Technical Heat Transfer Seminars under the guidance of the top men in this field.

Wolverine Tube has also given special and extensive heat transfer and integrally-finned tube training to a number of Heat Transfer Specialists who operate on a national basis. The services of these men are available to the heat transfer industry at large. Those desiring specific finned-tube knowledge can also draw on Wolverine's large library of product literature and catalogs.

There is an American business maxim that says "*For qualified guidance you must seek a qualified source.*"

You'll find that where integrally-finned tubing is concerned Wolverine Tube is indeed such a source.

WOLVERINE ALLOY CODE

CODE NO.	ALLOY	WT./FT. CONVERSION FACTOR (Wt./Ft. of Copper x Conv. Factor= Wt./Ft. of alloy)
01	Copper	1
25	Admiralty (Type C)	.9531
26	Admiralty (Types B & D)	.9531
28	85/15 Red Brass	.9780
30	Aluminum Brass (Type B)	.9319
40	1100 Aluminum	.3032
41	3003 Aluminum	.3065
50	Nickel	1
51	70/30 Cupro-Nickel	1
53	90/10 Cupro-Nickel	1
54	Monel	1
60	Low Carbon Steel	.8761
70	Stainless Steel	.8978

Example: *Wolverine Trufin type S/T*
Catalog No. 60-195065-26

60	19	5	065	26
TYPE S/T	FINS PER INCH	ROOT DIA. IN 1/8 OF INCH	WALL AT FIN	ALLOY

TRUFIN TYPE H/A

19 FINS PER INCH

NOMINAL SIZE O.D.	CATALOG NO.	PLAIN SECTION DIMENSIONS O.D.	Wall Thk.
5/8	60-194028	.625	.042
	60-194035		.049
	60-194042		.058
	60-194049		.065
	60-194065		.083
3/4	60-195028*	.750	.049
	60-195035		.052
	60-195042		.058
	60-195049		.065
	60-195065		.083
	60-195083		.095
7/8	60-196035*	.875	.054
	60-196042		.058
	60-196049		.065
	60-196065		.083
	60-196083		.095
1	60-197042	1.000	.058
	60-197049		.065
	60-197065		.083
	60-197083		.095

TRUFIN TYPE L/C—BIMETAL

TRUFIN TYPE H/R

TRUFIN TYPE S/T

TRUFIN TYPE S/T—DUPLEX

FINNED SECTION DIMENSIONS				OUTSIDE AREA	SURFACE AREA RATIO	I.D. CROSS SECTIONAL AREA In Sq. Inches	APPROX. WT./FT. LBS. (Copper)	AVAILABLE ALLOYS (See Attached Code)
Root Dia.	Wall Thk.	Inside Dia.	d_o	Sq. Ft. per Linear Ft.	a_o/a_i			
.500	.028	.444	.535	.405	3.48	.155	.283	
	.035	.430			3.60	.145	.320	01, 53, 40, 41, 50
	.042	.416			3.72	.136	.356	
	.049	.402			3.85	.127	.391	
	.065	.370			4.18	.108	.466	01, 53, 51, 40, 41, 50, 28, 25, 26, 60
.625	.028	.569	.660	.496	3.33	.254	.353	
	.035	.555			3.41	.242	.401	01, 53, 40, 41, 50
	.042	.541			3.50	.230	.448	
	.049	.527			3.60	.218	.493	
	.065	.495			3.84	.192	.593	01, 53, 51, 40, 41, 50, 28, 25, 26, 60
	.083	.459			4.13	.166	.697	
.750	.035	.680	.785	.588	3.30	.363	.485	
	.042	.666			3.37	.349	.541	01, 53, 40, 41, 50
	.049	.652			3.44	.334	.597	
	.065	.620			3.62	.302	.721	
	.083	.584			3.85	.268	.853	01, 53, 51, 40, 41, 50, 28, 25, 26, 60
.875	.042	.791	.910	.678	3.27	.492	.632	
	.049	.777			3.33	.474	.699	01, 53, 40, 41, 50
	.065	.745			3.48	.436	.847	
	.083	.709			3.65	.395	1.006	01, 53, 51, 40, 41, 50, 28, 25, 26, 60

*Plain lands are available on all standard Type S/T sizes except 195028 and 196035. All lands are supplied in the annealed condition. They are limited to a minimum length of one inch.

TRUFIN TYPE I/L

TRUFIN TYPE S/T
U-BEND FOR SHELL AND TUBE CONDENSERS

THE THINGS YOU MUST KNOW ABOUT FINNED TUBE

EXPERIENCE

Where finned tube and heat transfer experience is concerned, Wolverine Tube is the industry's acknowledged leader. Wolverine pioneered the development of integrally finned tube (Wolverine Trufin®) and over the years has produced millions upon millions of feet of this efficient extended surface for countless heat transfer installations throughout the United States.

HEAT TRANSFER SPECIALISTS

In addition to a fully staffed Field Engineering Service, Wolverine Tube also maintains Technical Heat Transfer Specialists in all major processing areas across the country. These men have all undergone intensive training in finned tube technology and have completed a Process Heat Transfer Course conducted by Donald Q. Kern, Wolverine consultant.

RESEARCH AND DEVELOPMENT

Wolverine Tube maintains the industry's most complete research and development facilities in Allen Park, Michigan. Here, day-in and day-out, research delving into all aspects of tubing manufacturing is carried out. Extensive research in finned tube and heat transfer has been conducted at the University of Michigan for many years in Wolverine's behalf. You can rest assured, as a result of all of these activities, that Wolverine Tube contributes its full share to the advancement of tubing technology. You can be sure, too, that because of these facilities you can place your complete trust in any product bearing the Wolverine name.

Next time you require finned tube—or have a tubing problem—consult Wolverine Tube. Either way you'll be sure of the finest product or soundest advice available.

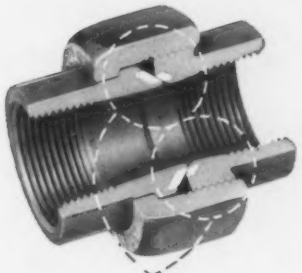
Wolverine Trufin is available in Canada through the Unifin Tube Division, London, Ontario.

WOLVERINE TUBE
DIVISION OF
Calumet & Hecla, Inc.
DEPT. B, 17236 SOUTHFIELD RD., ALLEN PARK, MICH.
Manufacturers of Quality-Controlled Tubing

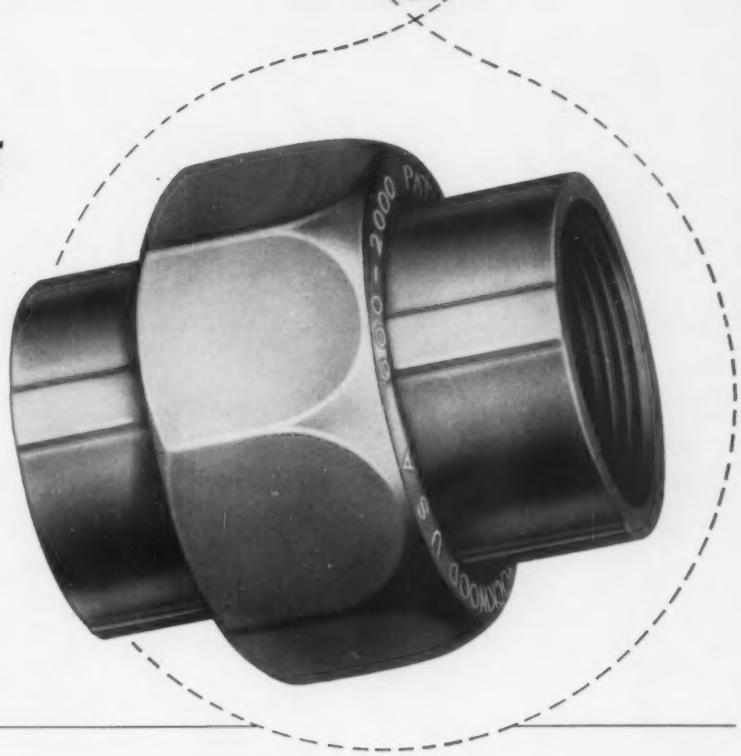
PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA
SALES OFFICES IN PRINCIPAL CITIES

In Rockwood Unions . . .

the big hardness differential in seats



makes a big difference in the entire union



In Rockwood Union #603 both seats are made of corrosion-resistant AISI molychrome steel, forged in place and double-locked under 100,000-pound and 400,000-pound pressures.

The male seat is specially heat treated to make it 150 Brinell harder than the female seat.

No other union has this hardness differential, which eliminates galling in make-up and assures long, trouble-free service life.

There are other big differences in Rockwood Unions that mean greater safety and economy. For example:

- an exclusive cold forging process results in easily interchangeable parts, all with highest resistance to shock, jar, vibration, expansion and contraction.
- balanced design distributes built-in strength uniformly throughout each Union.
- "Rockwoodizing," a special coating process, protects threads and all other surfaces against corrosion.
- Color-coding of different type Rockwood Unions enables easy identification by warehousemen and pipe fitters.

Rockwood Unions are tested and listed by Underwriters' Laboratories, Inc., for use with flammable liquids and gases. Write for complete facts.

ROCKWOOD SPRINKLER COMPANY
A Division of The Gamewell Company
Distributors in all principal industrial areas

ROCKWOOD SPRINKLER COMPANY
A Division of the Gamewell Company
720 Harlow Street
Worcester 5, Massachusetts

Please send me prices and further information on Rockwood Unions.

Name _____

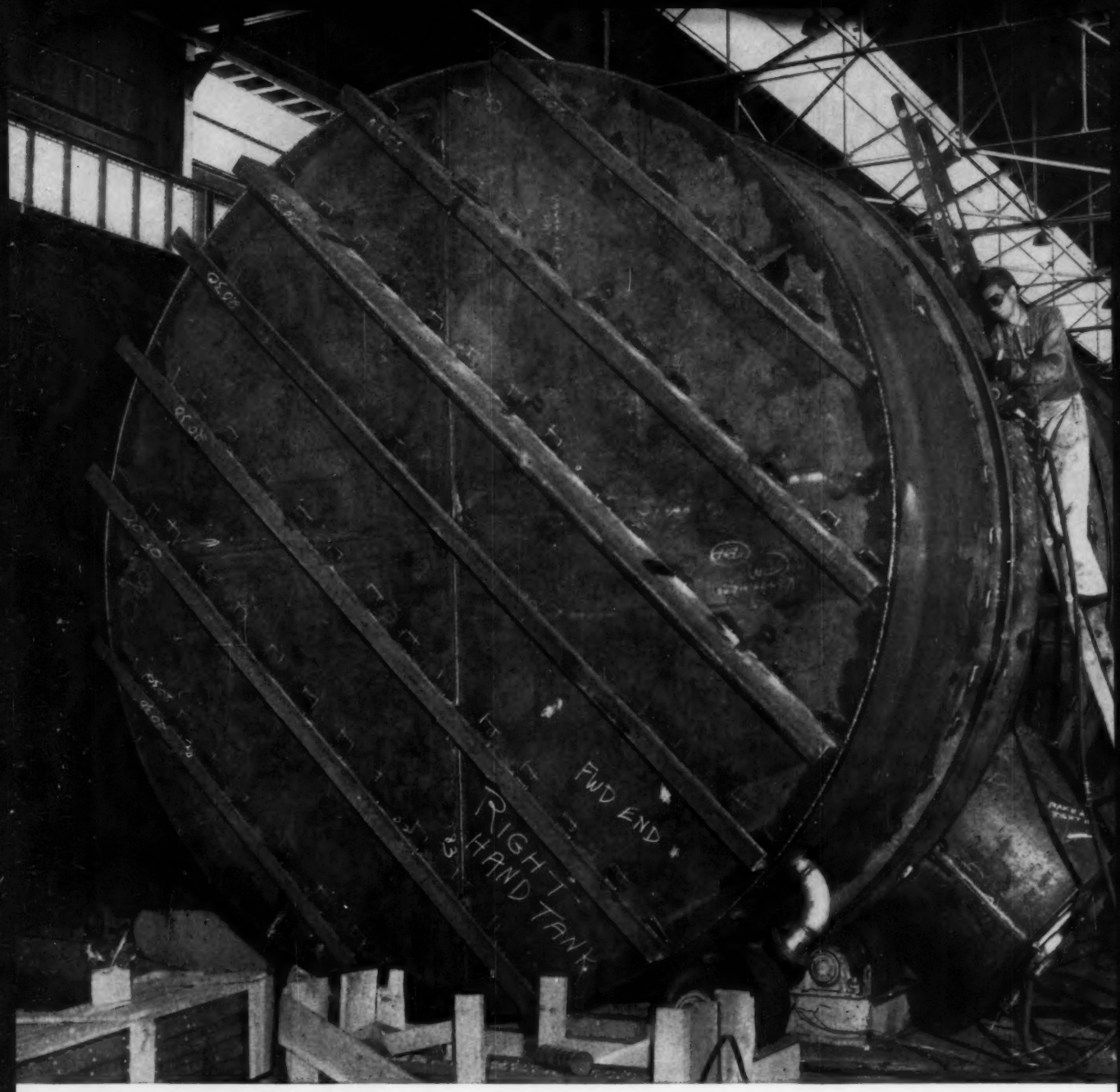
Title _____

Company _____

City _____ *Zone* ____

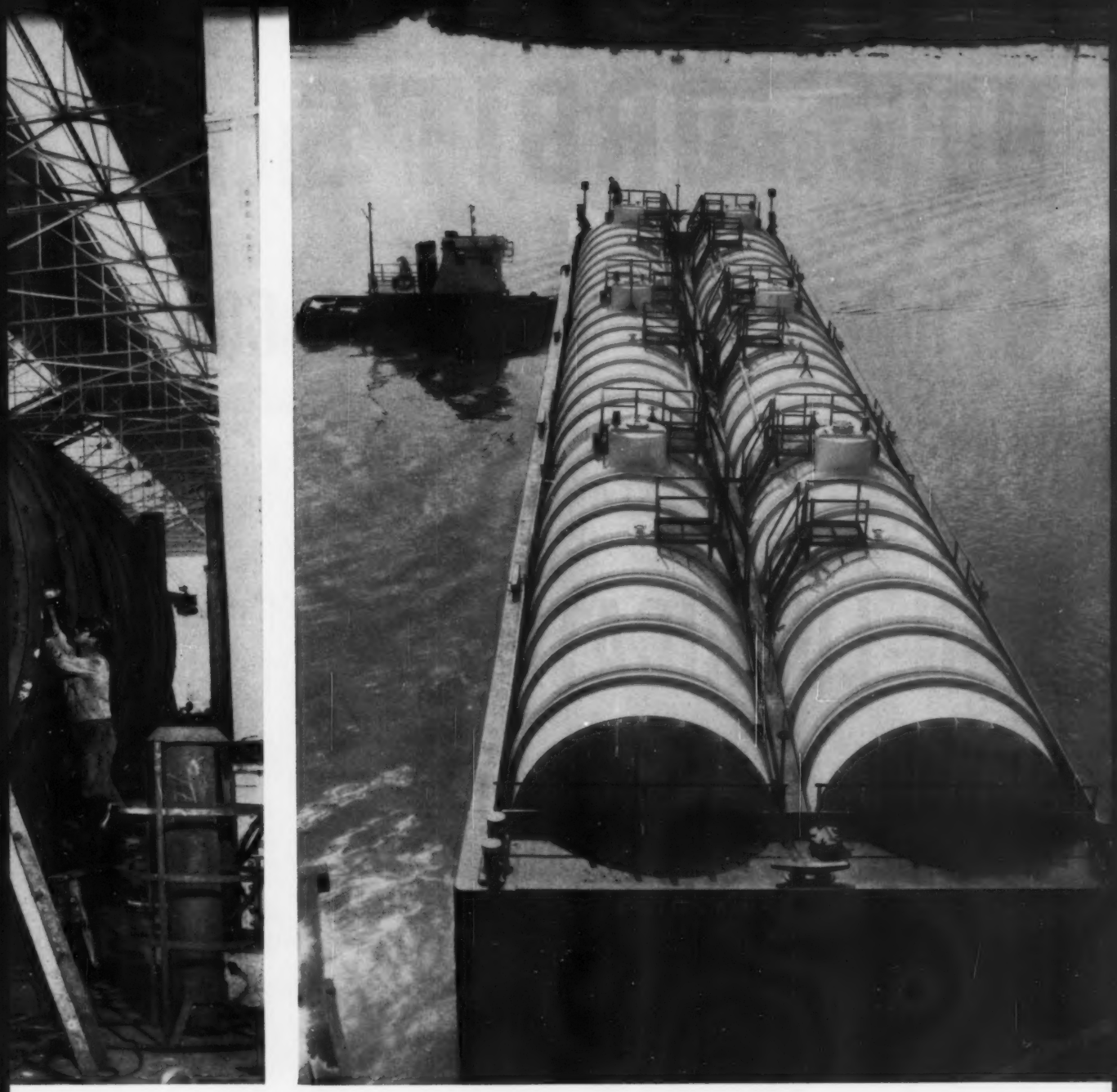
State _____

For more data on advertised products, use Readers' Service Cards, last page.



Tanks as big as a barge can carry

These new tanks have unobstructed interiors to carry maximum cargo with least danger of contamination—the essential requirements of an order for two independent tank barges from Union Carbide Chemicals Company. One barge is designed to carry Grade A and lower liquids having a Reid Vapor Pressure not exceeding 25 psi. The other barge will carry similar cargoes having a Reid Vapor Pressure not exceeding 40 psi. ☐ American Bridge designed and constructed the tanks and barges at its modern Plate Shop in Orange, Texas. The results: two Jumbo Hopper Barges 195′ x 35′ containing six tanks 52′ long x 14′-6″ O.D. and weighing 22 tons with a total



capacity of 383,000 gals. per barge. The reinforcing members for the tanks were placed on the tank exteriors leaving unobstructed nickel-plated interiors. ☐ Whatever your plate needs, we have the staff and facilities to take care of them, and our strategic location permits shipment by train, truck or barge. Write for our booklet completely describing plate fabricating and construction services.

USS is a registered trademark

General Offices: 525 William Penn Place, Pittsburgh, Pa.
Contracting Offices in: Ambridge • Atlanta • Baltimore • Birmingham • Boston • Chicago • Cincinnati Cleveland • Dallas • Denver • Detroit • Elmira • Gary • Harrisburg, Pa. • Houston • Los Angeles Memphis • Minneapolis • New York • Orange, Texas • Philadelphia • Pittsburgh • Portland, Ore. Roanoke • St. Louis • San Francisco • Trenton • United States Steel Export Company, New York

American Bridge Division of United States Steel

USS

NOW — ORBIT'S new 6" full opening ASA 300 & 600 lb. VALVES with combination seating of TEFLON* and metal to metal.

NON-LUBRICATED for low cost maintenance and product protection.

PLUS: these additional features

- Low opening and closing torque for easy operation
- A minimum of working parts for long, trouble-free performance
- Adjustable plastic stem packing — can be added to while valve is in service and under pressure
- Positive shut-off

FOR:

Ethylene — Propane — Butane — Refinery Gases

Natural Gas — Gas Gathering Systems.

Hydrogen — Nitrogen — Ammonia.

Carbon Dioxide — Industrial Gases.

*Registered Trade-Mark for du Pont's "TFE — fluorocarbon"

Write us for detailed material and dimensional specifications on these 6" Full Opening Valves which conform to ASA Standards. Flanged Ends only. Raised Face or Ring Joint.

low priced

ORBIT VALVES®

ORBIT'S NEW 6" FULL OPENING VALVE
AVAILABLE IN ASA 300 AND 600 POUND RATINGS
RAISED FACE OR RING JOINT—FLANGED END ONLY

ORBIT VALVES®

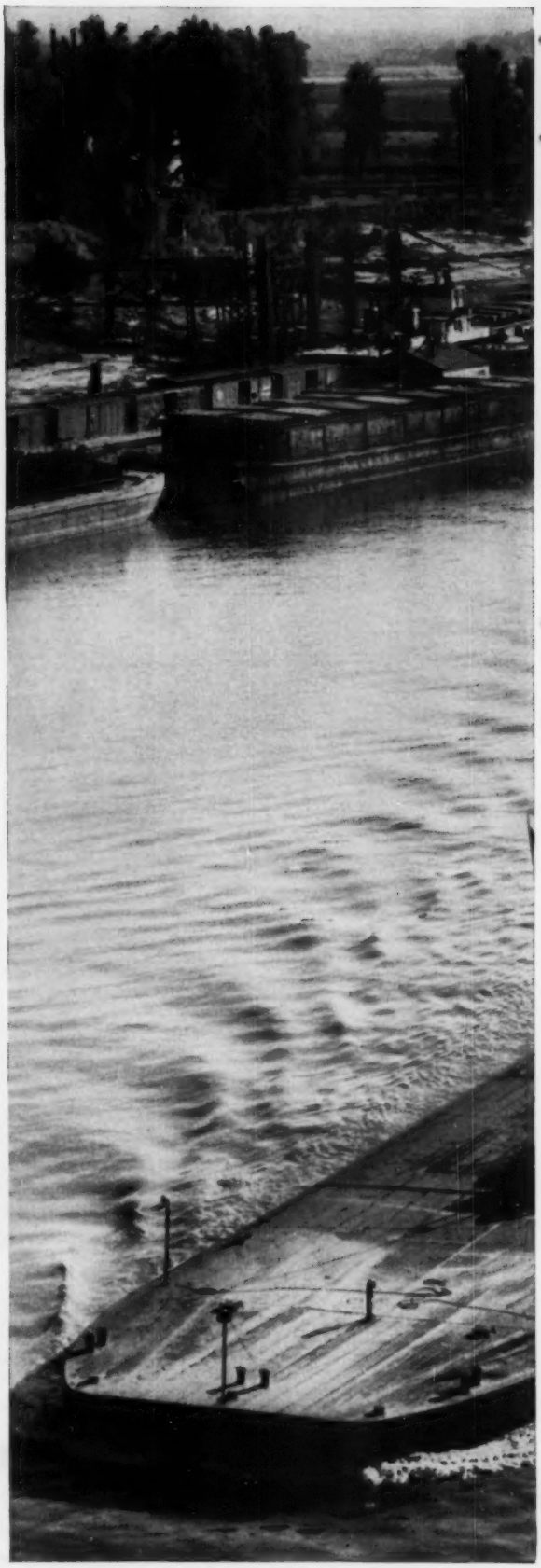
ORBIT VALVE COMPANY

P. O. BOX 699 TULSA, OKLAHOMA
PHONE LUther 4-4761 TWX TU 925

For more data on advertised products, use Readers' Service Cards, last page.

ARMOUR FUEL OIL ADDITIVES –

How they protect against sludge from refinery to furnace



Armolad® additives, Armour's furnace-oil stabilizers, are gaining wide acceptance as highly economical and effective sludge inhibitors. Using Armolads, refiners can stop worrying about additives that lose effectiveness while in transit or storage.

Fuel oil additives are subject to various conditions which can reduce their sludge-inhibiting properties. Major causes are: incompatibility with other additives, reaction with fuel contaminants themselves, and the presence of water—particularly in barges and storage tanks—which causes "leaching." Maintaining the effectiveness of the additive can only be achieved by increasing the concentration, which in turn raises costs unnecessarily.

Refiners using Armolads have found they are extremely resistant to water extraction, compatible with most other additives, help eliminate hazing, and will not react with fuel contaminants.

In addition, when fuel oil containing Armolads is pumped through the lines, monomolecular adsorption places a thin coating of the additive on the surfaces. This film offers resistance to corrosive action.

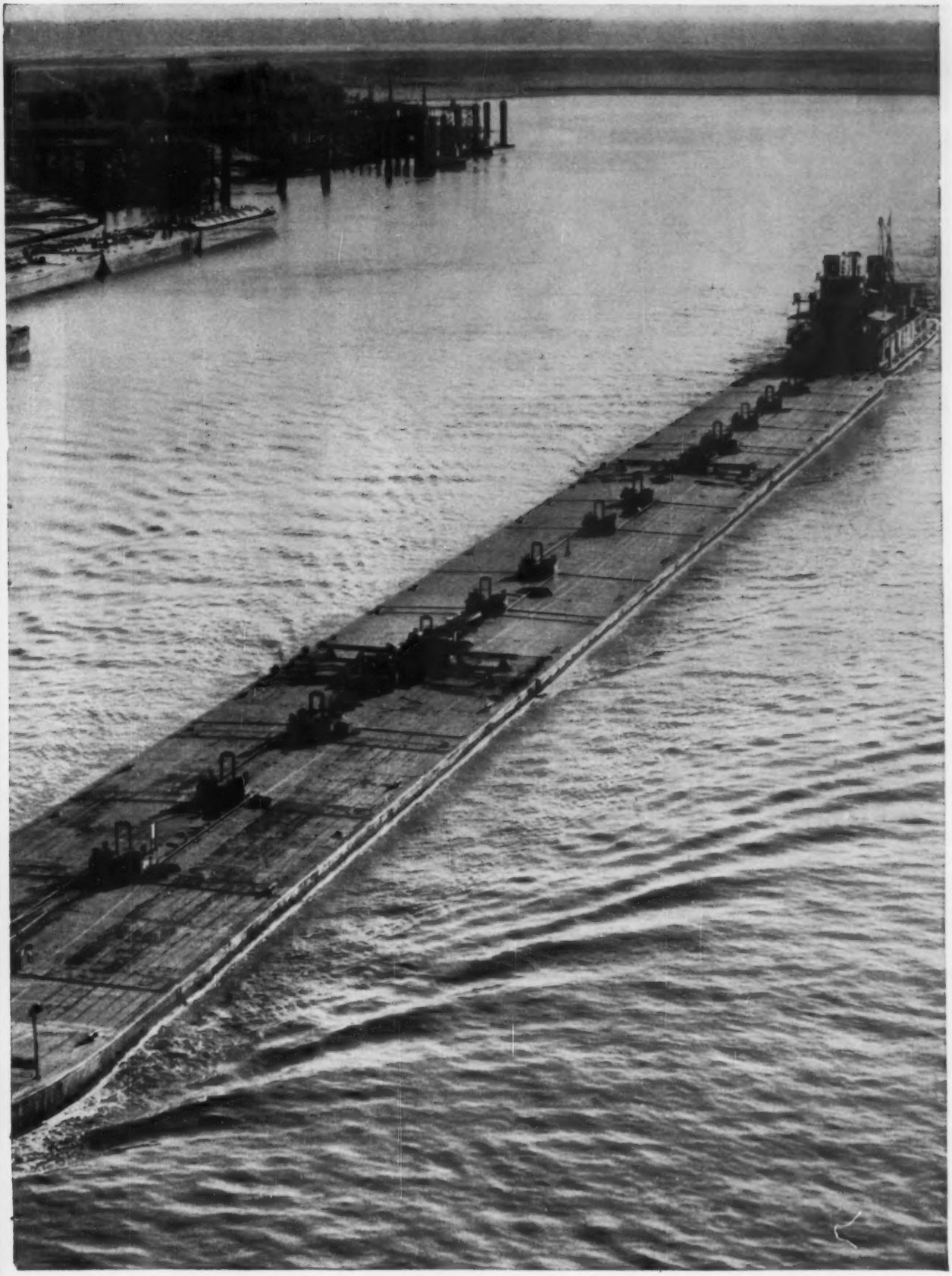
Armolads are available in several different formulations. Each has been found to suit the special needs of specific crude stocks. Additional information on these additives and their use is available by writing for the new booklet "Armolads."

Armour Industrial Chemical Company

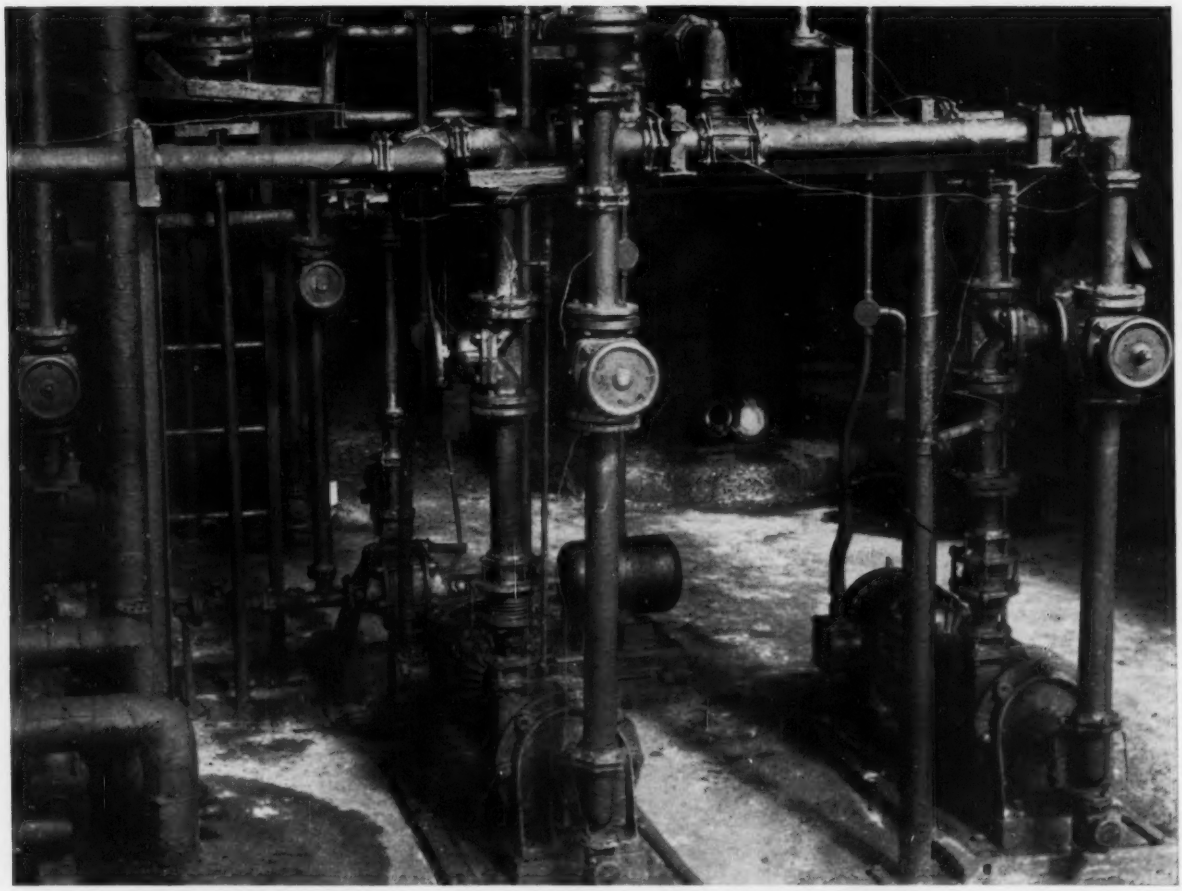
© *Division of Armour and Company*

110 NORTH WACKER DRIVE • CHICAGO 6, ILLINOIS

For more data on advertised products, use Readers' Service Cards, last page.



For more data on advertised products, use Readers' Service Cards, last page.



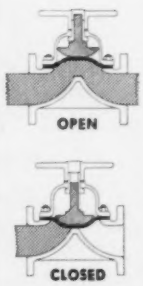
Glass-lined Grinnell-Saunders Valves, with Teflon Diaphragms, on benzene hexachloride lines at Diamond Alkali's Greens Bayou, Texas, plant. Hundreds of other Grinnell Diaphragm Valves are used in other areas of the plant.

How a manufacturer of benzene hexachloride solved a serious valve leakage problem

Valving at Diamond Alkali's Greens Bayou, Texas, plant had become expensive. Leakage of a product containing 30% to 40% benzene and free chlorine released fumes and caused rapid corrosion of the metal parts of the valves used previously, as well as of adjacent equipment.

This problem was corrected when Grinnell-Saunders Diaphragm Valves were used. The first replacement of any part of the Grinnell Valves did not occur for two years, and this was the diaphragm *only*. The former valves had to be *completely* replaced every one to two months! Bodies of the Grinnell valves lasted four years. In short, when Grinnell-Saunders Diaphragm Valves were installed, stem leaks ceased; corrosion was eliminated; and downtime to install new valves was practically ended.

For further facts about Grinnell-Saunders Valves, see Grinnell's insert in Chemical Engineering Catalog, or Sweet's Plant Engineering File — or write directly to Grinnell Company, Providence 1, Rhode Island.

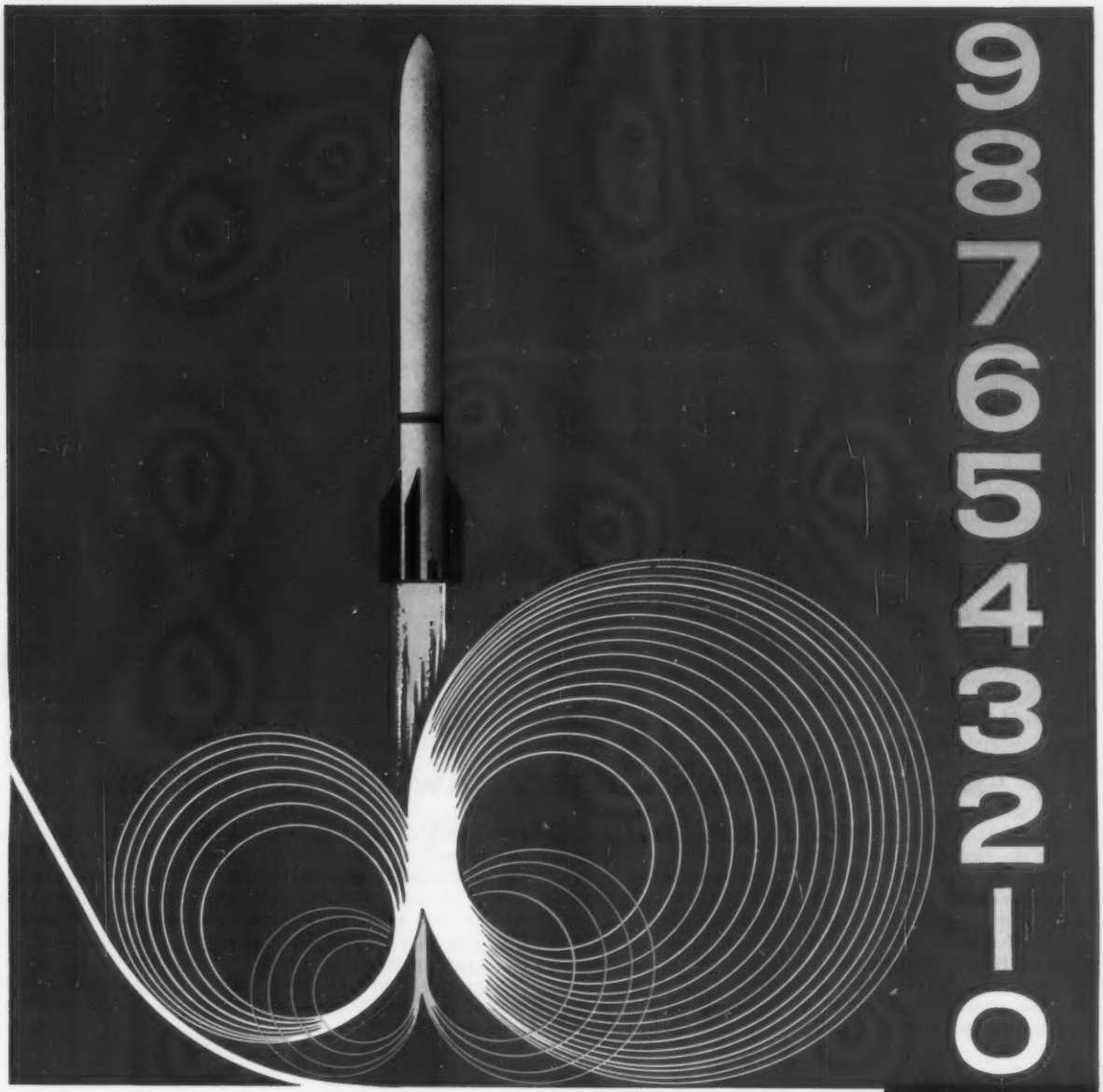


- Diaphragm lifts high for streamline flow in either direction
- Diaphragm presses tightly to effect positive closure
- No packing glands to need attention
- Diaphragm easily replaced without removing valve body from the line
- Wide choice of body, lining and diaphragm materials

GRINNELL-SAUNDERS DIAPHRAGM VALVES

GRINNELL COMPANY, PROVIDENCE 1, R. I. • BRANCH WAREHOUSES AND DISTRIBUTORS FROM COAST TO COAST
PIPE FITTINGS • VALVES • PIPE HANGERS • PREFABRICATED PIPING • UNIT HEATERS • PIPING SPECIALTIES

For more data on advertised products, use Readers' Service Cards, last page.



hot countdown . . . cool blastoff

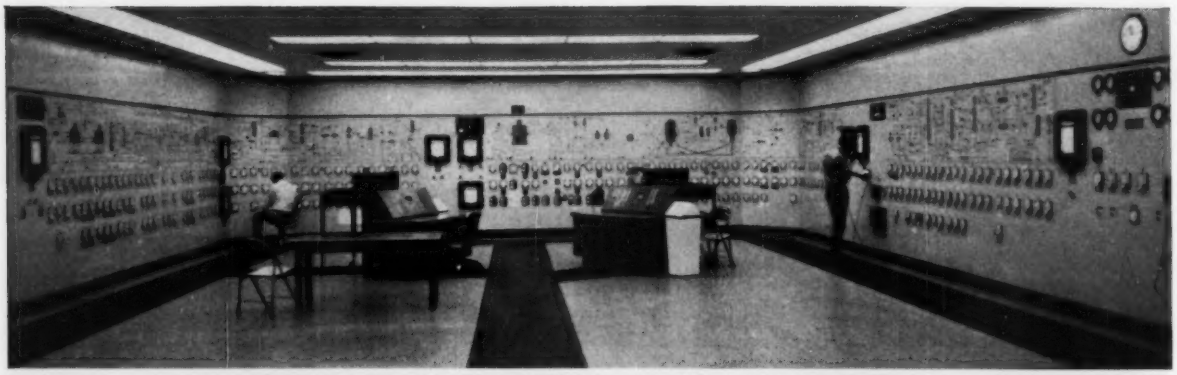
sophisticated piping systems use BONNEY SWEEPOLETS for branch connections

Bonney Sweepolets are in use on the Saturn missile launching pad on the high velocity water cooling system of the blast deflector. The long sweep of the Sweepolet provides maximum fluid flow and its sophisticated design provides optimum stress distribution. For all piping systems involving unusual or complex stresses at branch connections, you will be wise to specify Bonney Sweepolets. Write for catalog S-1A.

also exclusive manufacturers of
WELDOLETS®
THREDOLETS®
SOCKOLETS®
ELBOLETS®
BRAZOLETS®
• • • • • • • • • • • • • •
CARBON STEEL
STAINLESS
ALLOY
for all services

BONNEY FORGE AND TOOL WORKS, ALLENTOWN, PENNSYLVANIA

For more data on advertised products, use Readers' Service Cards, last page.



Bristol Metagraphic recorders and indicators occupy lower three rows on panel (shown in two photos above).

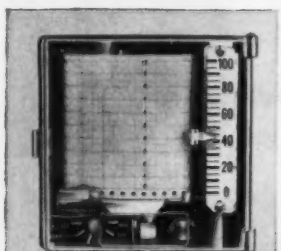
"NERVE CENTER" AT BIG NEW TEXACO PLANT INCLUDES BRISTOL METAGRAPHICS

This model central control room is the nerve center for a vast petroleum processing complex. It's located in the new Puget Sound Works of Texaco Inc., at Anacortes, Washington.

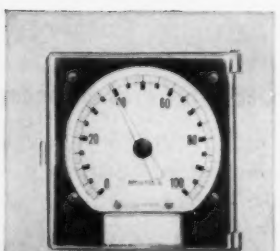
A key feature of the control system is a battery of several hundred Bristol Metagraphic pneumatic recorders, indicators, and controllers (lower three instrument rows on panel). The new plant produces motor gasolines, jet fuels, liquefied petroleum gases (LPG), diesel fuel, furnace oil, and heavy fuel oil. Crude oil capacity is 45,000 barrels per calendar day.

This is just one of hundreds of installations of Bristol Metagraphic instruments in use today in processing plants throughout the country. These compact instruments are ideal for graphic panel use, or where true "plug-in" versatility is necessary to insure maximum control system reliability and continuity of service. We'll be glad to send you the complete Metagraphic story. O.34

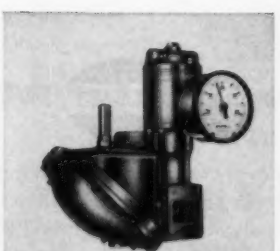
...and behind every panel, precision



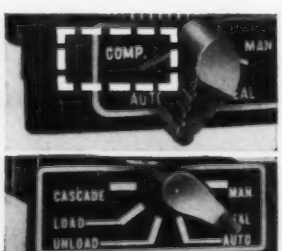
Metagraphic Recording Receiver... plugs and unplugs in 5 seconds. More than 36 pneumatic models, many electronic Dynamaster® potentiometer and bridge instruments—all with easy-to-read, human-engineered scales and charts.



Metagraphic Indicating Receiver... feature 9 inches of effective scale length, complete 10-second interchangeability with recorder of same type. Functionally colored pointers, plus long scale length makes distant reading easy.



Metagraphic Pneumatic Transmitters measure temperature, pressure, vacuum, absolute pressure, differential pressure, flow, liquid level or mechanical motion. Transmit on universal 3-15 psi pneumatic signal.



Pneumatic Control Stations allow utmost in operating flexibility. Four-position station (top) for computer-controlled refineries and chemical plants. Six-position station (bottom) for bumpless transfer in cascade systems. Many others available.

For more data on advertised products, use Readers' Service Cards, last page.

regardless of the nature of your measurement or control problem,

Bristol has matching miniature instruments for it

• Pneumatic transmission and control • Electronic potentiometers and bridges • Instruments for process computer systems • Electronic measurement—pneumatic transmission • Telemetering instruments • Recording gauges

Now, for the first time, you can get matching instruments for graphic panels, consoles, or other set-ups for all your process requirements—including electronic, pneumatic, telemetering, and gauge measurements. Bristol miniature instruments all have 5" x 5⅛" panel dimensions, fit 4 9/16" square cutout, and harmonize perfectly with each other.

Pneumatic Transmission. Bristol Pneumatic Metagraphic receivers operate on a universal 3-15 psi signal. They indicate or record *pressure, differential pressure, absolute pressure, liquid level, flow, temperature, mechanical motion and many other variables.* Indicators and recorders interchange on a full plug-in basis. There are 36 receivers, 38 controllers, and widest variety of transmitters in the industry to choose from.

Process Computer Control Instrumentation. Now available: two entirely new Metagraphic control stations, for use with process control computer systems.

Dynamaster* Electronic Potentiometers and Bridges, using same time-proven principles as full-size instruments, can provide measurements from such electrical sensing elements as thermocouples, strain gauges, pH electrodes, photoelectric cells, etc. Same high accuracy and reliability as full-size Dynamaster instruments.

Electronic Measurement—Pneumatic Transmission. The Miniature Dynamaster Electronic Potentiometer and Bridge Instruments, described above, are now available as pneumatic transmitters—3-15 psi signal. They will make any measurement that can be transduced to an electrical quantity and transmit that measurement pneumatically for Metagraphic recording, indicating, and automatic control.

Telemetering. Metameter* telemeter receivers, in 5" x 5⅛" case, can receive the same measurements from remote locations as their full-size counterparts. Can be installed miles from transmitter center.

Standard Pressure Gauges . . . now also offered in miniature-case, plug-in and non-plug-in types. Ranges from 0-3 through 0-100 psi.

For complete data, write The Bristol Company, 111 Bristol Road, Waterbury 20, Conn.

**T.M. Reg. U.S. Pat. Off.*

BRISTOL measurement and control

Series 663 Electronic Dynamaster potentiometer. Motor can drive almost any auxiliary devices — retransmitting slidewires, alarm contacts, analog-to-digital encoders. Available for electronic measurement—pneumatic transmission.

Metagraphic Pneumatic Controllers can plug in on receiver case, as shown here, or directly at controlled process. Proved force-balance operating principle requires almost no moving parts, nothing to wear out. 38 different models.

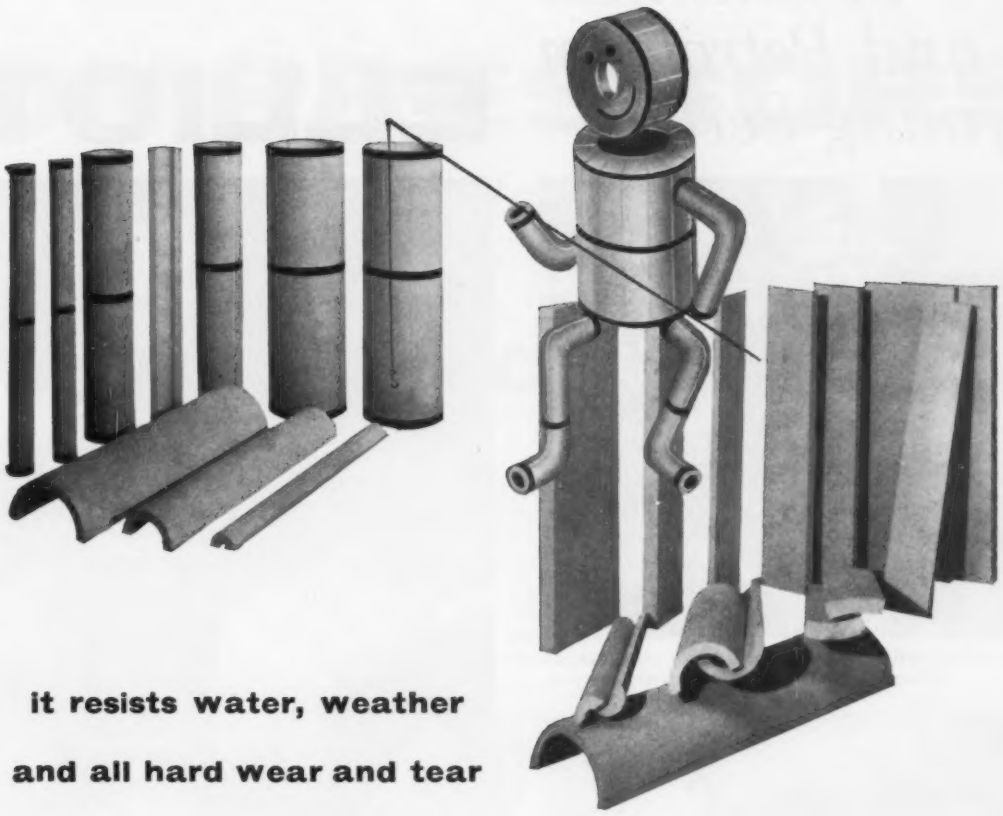
BRISTOL

for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

For more data on advertised products, use Readers' Service Cards, last page.

Darlington 85% Super-Magnesia
A NEW
EXCLUSIVE
INSULATION
PRODUCT



it resists water, weather

and all hard wear and tear

Darlington precision-moulded 85% Super-magnesia is a new and improved form of 85% Magnesia insulation possessing many superior physical characteristics. In particular, its form and efficiency are unimpaired by steam, water or adverse weather conditions; also it has a very high compressive strength with good rigidity which enables it to withstand all mechanical shock and wear and tear. Costing no more than ordinary 85% Magnesia material, Darlington Super-magnesia is a product *exclusive* to The Chemical & Insulating Co. Ltd.

Here are some of the special features of 'Supermag'

WATER-RESISTANT. Even boiling in water for twenty-four hours has no effect on the shape and form of Super-magnesia! It is a material of particular value for external or humid conditions.

WITHSTANDS CRUSHING. The compressive strength of Darlington Super-magnesia is double that of normal 85% Magnesia. It may be used quite safely as a catwalk, or to support ladders.

EXCEPTIONAL ROBUSTNESS. An actual chemical bond which takes place in the material during manufacture makes it stronger and more resistant to damage and vibration.

LOW THERMAL CONDUCTIVITY. Darlington Super-magnesia has a better resistance to heat flow, particularly at lower temperatures. It may be used satisfactorily at temperatures up to 650°F.

PRECISION MOULDED. Super-magnesia is cast to precise dimensions and shapes to ensure a snug and exact fit.

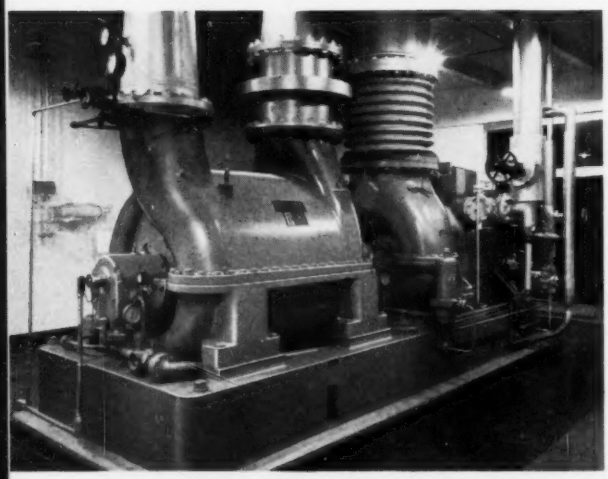
CLEAN AND EASY TO HANDLE. Super-magnesia has a smooth, white finish free from 'fluffiness'. It may be sawn and cut to shape easily, and without mess.

Remember — Darlington 'Supermag' costs no more than ordinary 85% Magnesia!
For further information and technical details write to:

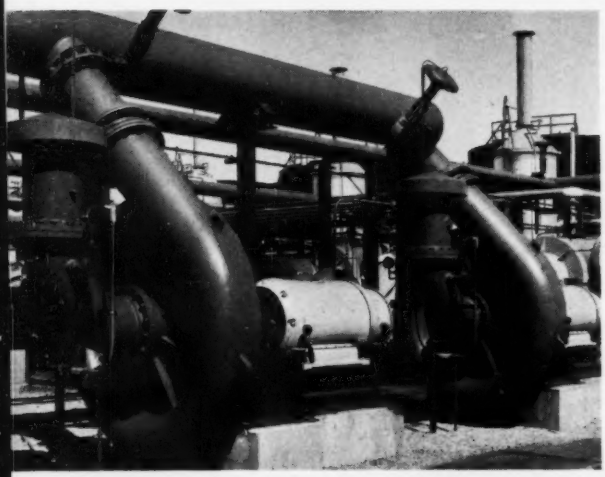
The Chemical and Insulating Co. Ltd., Darlington, County Durham.
A MEMBER OF THE DARLINGTON GROUP OF COMPANIES

in Chemical and Petroleum Refining Service–

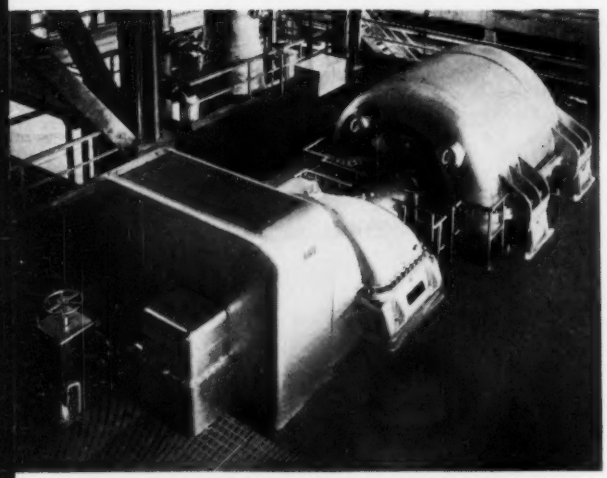
ELLIOTT



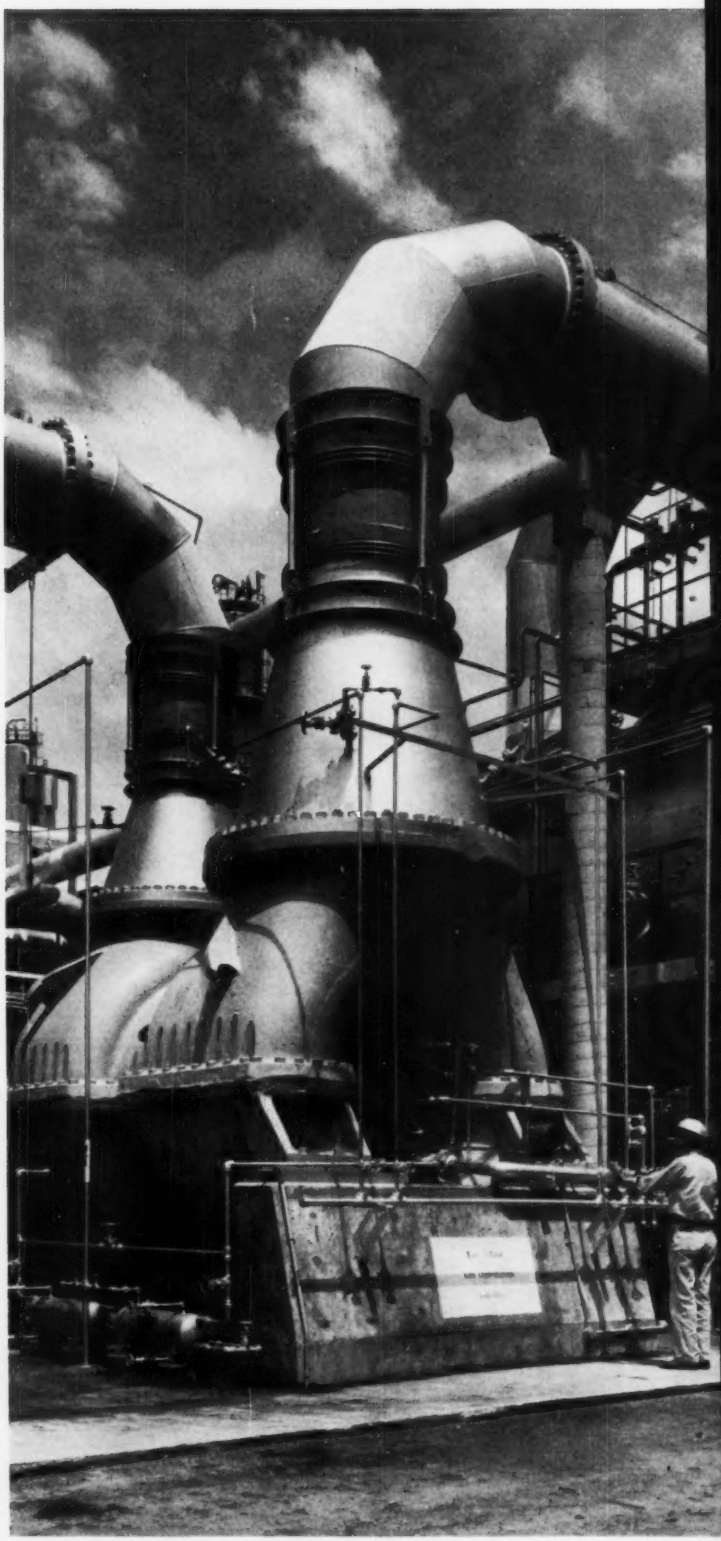
Elliott multi-stage compressor with 2035-hp Elliott turbine drive, in refinery service.



Two single-stage Elliott compressors driven by Elliott motors.



One of the largest turbine-driven multi-stage compressors ever installed, for fluid catalytic cracking unit.



One of the large axials serving a Petro-Chemical plant.

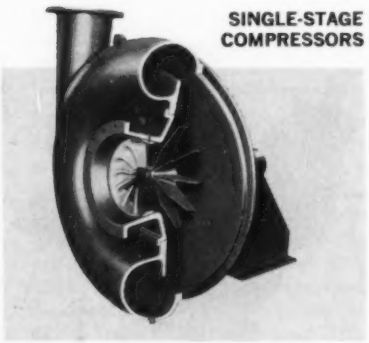
COMPRESSORS

Today's most complete line of centrifugal and axial machines from **500** *cfm to* **600,000** *cfm*

48 FRAME SIZES WITH MATCHING DRIVERS

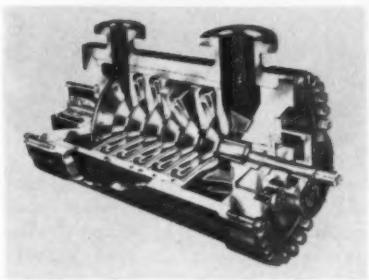
With this, the most-complete line of centrifugal and axial compressors available today—Elliott offers an unexcelled range of choice of established machines. In addition, there is the extra advantage of matching Elliott turbine or motor drivers. Both units engineered and built by Elliott is a decided "plus" because it means unified responsibility, unified service.

SINGLE-STAGE COMPRESSORS



Elliott single-stage centrifugal compressors range in size from 700 to 100,000 icfm and above. They are readily adaptable to special service conditions, and to the handling of corrosive or dirty gases. A variety of impeller designs, bearings, seals, and materials of construction permits each unit to be tailored to its particular application.

MULTI-STAGE CENTRIFUGAL COMPRESSORS



Elliott multi-stage compressors are made in a wide variety of sizes and styles, to serve many difficult and exacting applications. They are available with inlet capacities up to approximately 150,000 icfm. Impellers, casings, internal passages and bearings for each type of machine have been designed to provide smoothly operating, rugged, dependable machines.

AXIAL FLOW COMPRESSORS

Multi-stage compressors of the axial flow type are designed and engineered specifically to serve the needs of industry for the handling of air or gas mixtures in large volume flow operation. Applications include petroleum refining, chemical processing and the steel industry. Frame sizes are rated up to approximately 600,000 cubic feet per minute when operating on air.

MATCHED MOTOR OR TURBINE DRIVE

Elliott is a leading manufacturer of both steam turbines and electric motors, of all types and ratings necessary to provide driving power for the compressor units described above. Consequently, we are in position to recommend and furnish the type of drive best suited for each application.

FOR AIR OR GASES

Elliott integrated compressor units are available for handling all types of compressible fluids, within the pressure and flow limits of the machines. Where corrosive gases are handled, special materials are employed in vulnerable spots; where high pressures are needed, extra heavy construction is used; where leakage must be prevented, special shaft seals are available; where high temperatures must be avoided, provision is made for cooling.

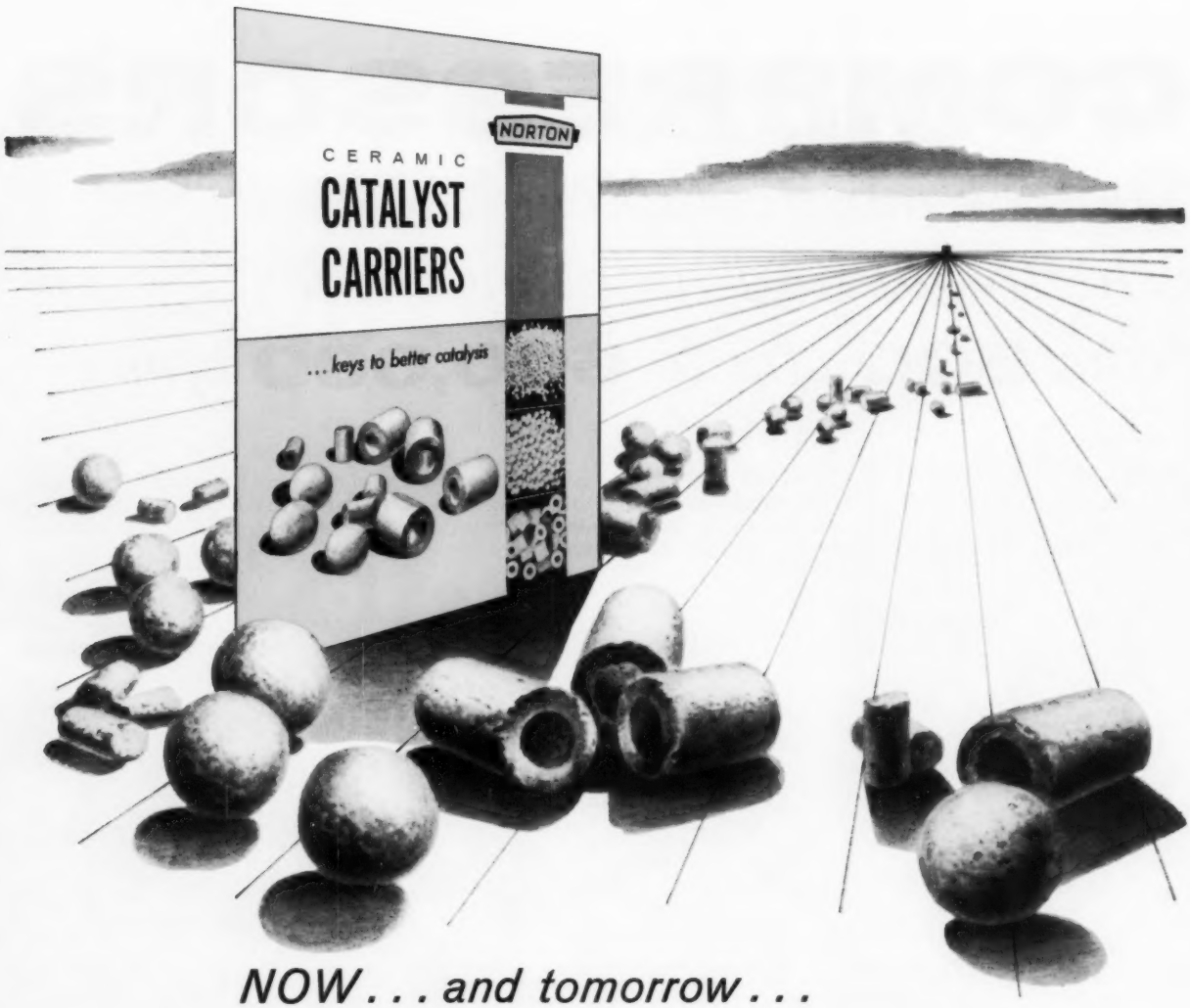
48 STANDARD FRAME SIZES

The total of 48 frame sizes permits accurate application for all compressor problems over the entire range of 500 cfm to 600,000 cfm. Pressures and speeds can be selected to meet the characteristics of the application, and the gas to be handled. *For further information, write Compressor Department, Jeannette, Penna.*

ELLIOTT THE MOST COMPLETE LINE OF **INTEGRATED COMPRESSOR & DRIVER UNITS** 500 cfm to 600,000 cfm

ELLIOTT Company
Jeannette, Penna.

PO-1



NOW . . . and tomorrow . . .

choose NORTON Ceramic Catalyst Carriers

In columns and reactors throughout the chemical and petrochemical industries, NORTON Ceramic Catalyst Carriers are helping processors to improve catalyst activity and life, lower catalyst costs, get optimum yields from reactions.

It's *consistent* high performance too, because *every* NORTON Carrier is uniform in *any* quantity from lot to lot. Size, weight, porosity, and purity are held to close tolerances. Duplication of specifications is assured.

Today, probably the most widely-used NORTON Carrier is alumina . . . in ring, sphere, and pellet form and as granules and powder. However, as new feedstocks are developed, and more demanding physical, chemical, and thermal conditions are encountered, new NORTON Carriers will be ready to meet catalysis specifications. For example, various materials are now available in experimental quantities as spheres, rings and pellets . . . in alumina, magnesia-alumina spinel, fused magnesium oxide, silica, zircon, zirconia and silicon carbide. These NORTON developments offer porosities ranging from 4% to 65%; surface areas from less than 1 to 70m^2/gram (BET method).

Also readily available is the technical assistance of the Norton Man. Through him, chemical engineers can draw upon the wealth of research and engineering data compiled over the years by the NORTON COMPANY. He is well qualified to help *you* meet catalyst carrier specifications exactly . . . efficiently . . . economically.

NORTON Carriers are described in detail in the Bulletin, "Keys to Better Catalysis". For your copy, or for technical assistance, write NORTON COMPANY, Refractories Division, 465 New Bond Street, Worcester 6, Massachusetts.

NORTON
REFRACTORIES
Engineered . . . By . . . Prescribed

75 years of . . . **Making better products . . . to make your products better**

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — **BEHR-MANNING DIVISION:** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

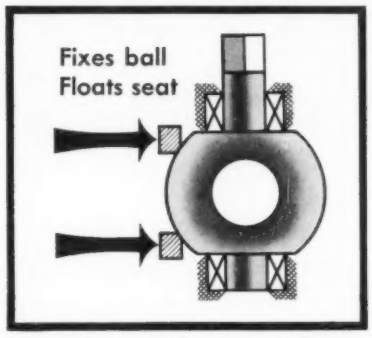
Can A Ball Valve Operate, Cycle After Cycle, With No Maintenance At All?

Read this remarkable answer, and discover an amazing engineering feat.

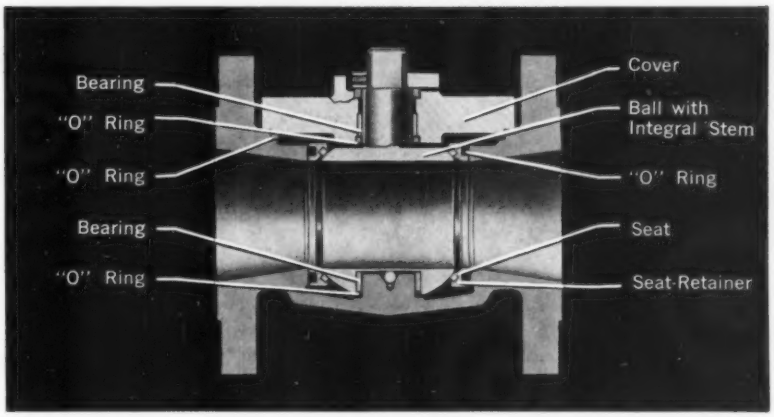
As most engineers know, ball valves offer a number of distinct advantages over all other types of valves . . . 90° on-off, minimum pressure drop, positive on-off indication, no lubrication, and compactness. In common with other valves, however, the design was insufficient to overcome the problem of continual maintenance.

Four years ago, this problem was faced by Hydromatics, Inc. in the valves that they produced for use in missiles, aircraft and ground support systems. Then, as today, all other ball valves were built with a ball that floated in its socket, and sealed by being forced against its seat by the pressure in the line. This caused seat distortion which made early replacement necessary.

Hydromatics tried a different approach. Rather than use the traditional floating ball, their engineers fixed the ball in bearings.



In the bearing-fixed **FLO•BALL** valve all pressure forces exerted on the ball are transmitted to low-friction bearings, thus eliminating down-stream seat distortion due to ball load. The pressure balanced seat, with its teflon sealing surface, is continually self-adjusted by the O-ring in the seat retainer.

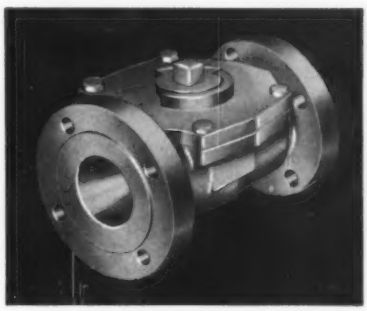


This O-ring acts as a self-energizing force that keeps the teflon seat always in contact with the ball. This insures positive sealing without seat distortion, and minimizes seat-resisting frictional forces. The combination of these low frictional forces results in low operating torque and extremely long seat life.

The bearing-fixed **FLO•BALL** valve proved itself immediately. Hundreds of missile and spacecraft systems, previously impossible, were made possible with these valves. The X-15, America's first manned space vehicle, for instance, has a Hydromatics **FLO•BALL** valve at its heart. Since its inception, the **FLO•BALL** has been used in more varied applications than all other ball valves combined.

Now, after the toughest application testing in history, bearing-fixed **FLO•BALL** valves are being mass produced for industry. They are available for off-the-shelf delivery to standard ASA dimensions in semi-steel, carbon steel, stainless steel, and aluminum. They operate at pressures to 600 psi, temperatures to 400°F and hold vacuum to 10^{-6} mm. of Hg!

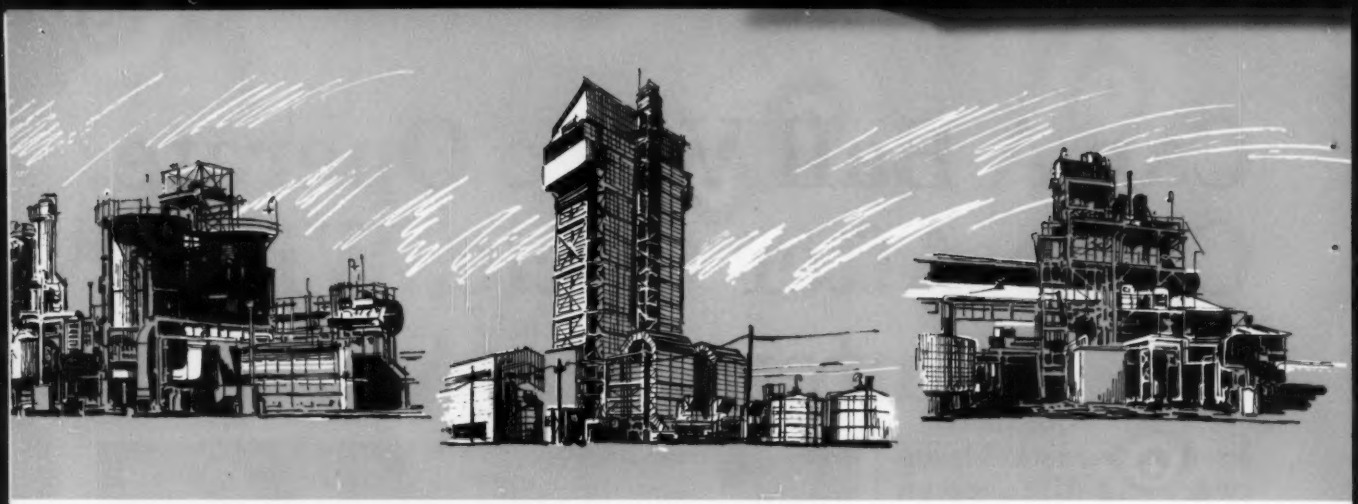
The bearing-fixed **FLO•BALL** offers extra ball valve advantages. Top loading for easy access without removing the valve from the line, plus three features that are absolutely unique! Self-adjusting seats which automatically compensate for wear, proportional sealing force which automatically increases with line pressure, and the lowest torque, by far, of any valve. These combine to make the **FLO•BALL** valve virtually maintenance-free!



How long does it last without maintenance? Frankly, we don't know, since the first valves we ever built are still going strong and outlasting other valve types by more than 10-to-1. But don't take our word for it. See for yourself. Call, write or TWX for further information.

Hydromatics, Inc.
Livingston, New Jersey
Telephone: WYman 2-4900
TWX-LIVINGSTON NJ 120

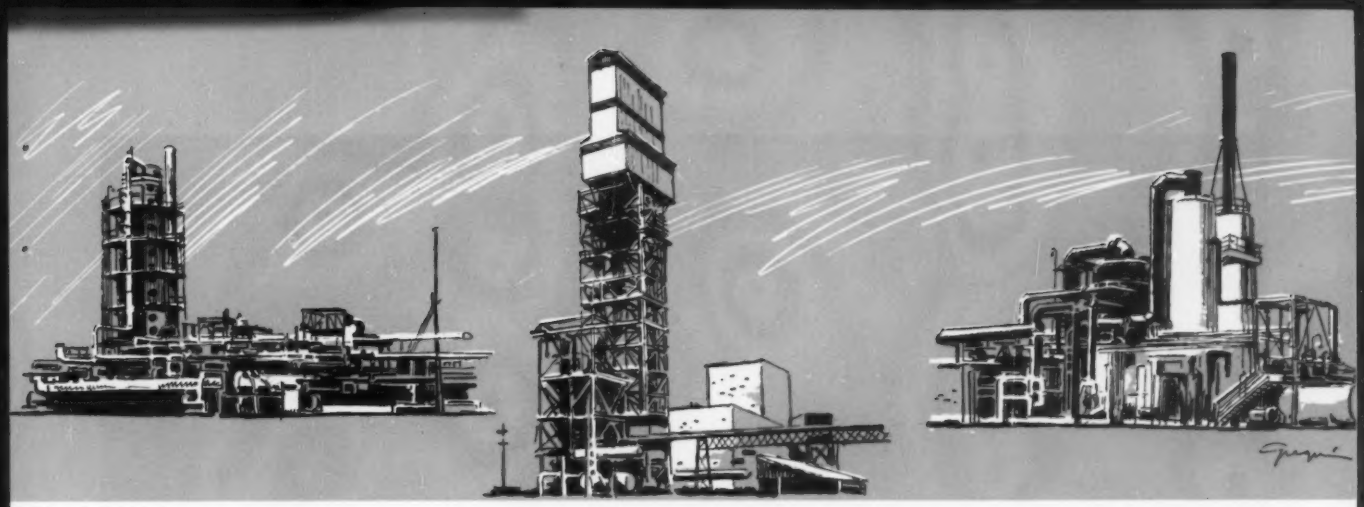
For more data on advertised products, use Readers' Service Cards, last page.



Chemicals for the soil...

Chemico has production-proven processes for the major fertilizer chemicals

ammonia / ammonium sulfate / ammonium nitrate
ammonium phosphate / superphosphate
triple superphosphate / urea / complex fertilizers
nitric acid / sulfuric acid / phosphoric acid



In India, Pakistan and Japan; in England, France and Italy; in Hawaii, Sumatra and Formosa; in Australia, South Africa and South America; in more than half the states of the Union and in every highly populated area on earth, Chemico-designed plants are producing basic fertilizer chemicals to increase world food production.

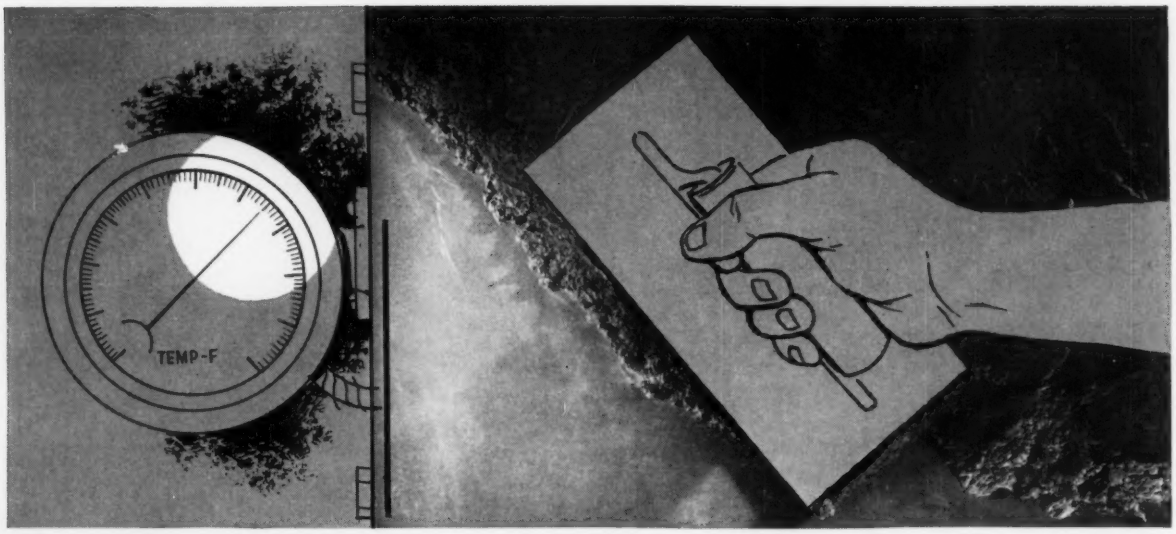
Chemico's experience in designing plants to produce fertilizer chemicals is unmatched by any other engineering company in the world. More than 200 Chemico sulfuric acid plants are now in operation. Sixty-five Chemico ammonia plants are on stream or under construction. In January of this year, Chemico completed its thirty-fourth nitric acid plant. Other Chemico plants now in production or under construction have capacities for producing 3,700,000 tons per year of ammonium sulfate and 1,600,000 tons per year of ammonium nitrate. When the capacity of the Chemico urea plants now under construction in Pakistan and the U. S. is added to what is being produced at plants in Japan, Canada and elsewhere in the U. S., the Chemico urea process will account for more than 400,000 tons per year.

Chemico's proven processes are transformed into efficient operating plants with maximum speed and with minimum expense to the client. Ease of start-up and low operating costs are just two of the more obvious advantages of Chemico plants. If your company is considering the construction of additional production facilities, or the expansion of your present plant, Chemico will help you find the most efficient and economical solutions to your process problems.

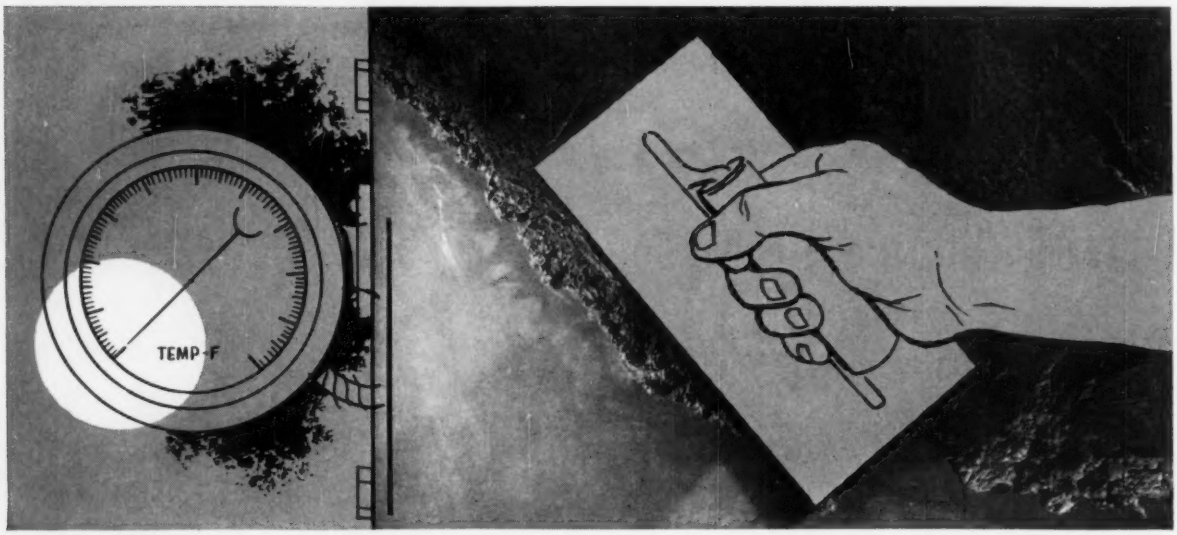
CHEMICO

CHEMICAL CONSTRUCTION CORPORATION
525 West 43rd Street, New York 36, New York

CHICAGO · DALLAS · PORTLAND, ORE. · HOUSTON · TORONTO · LONDON · PARIS · JOHANNESBURG · TOKYO



IT STICKS TO HOT OR COLD SURFACES!



EAGLE-PICHER
SUPER "66"
INSULATING CEMENT

Eagle-Picher produces a complete line of industrial insulations for all temperatures from below Zero to over 2000 F.

EAGLE EP PICHER

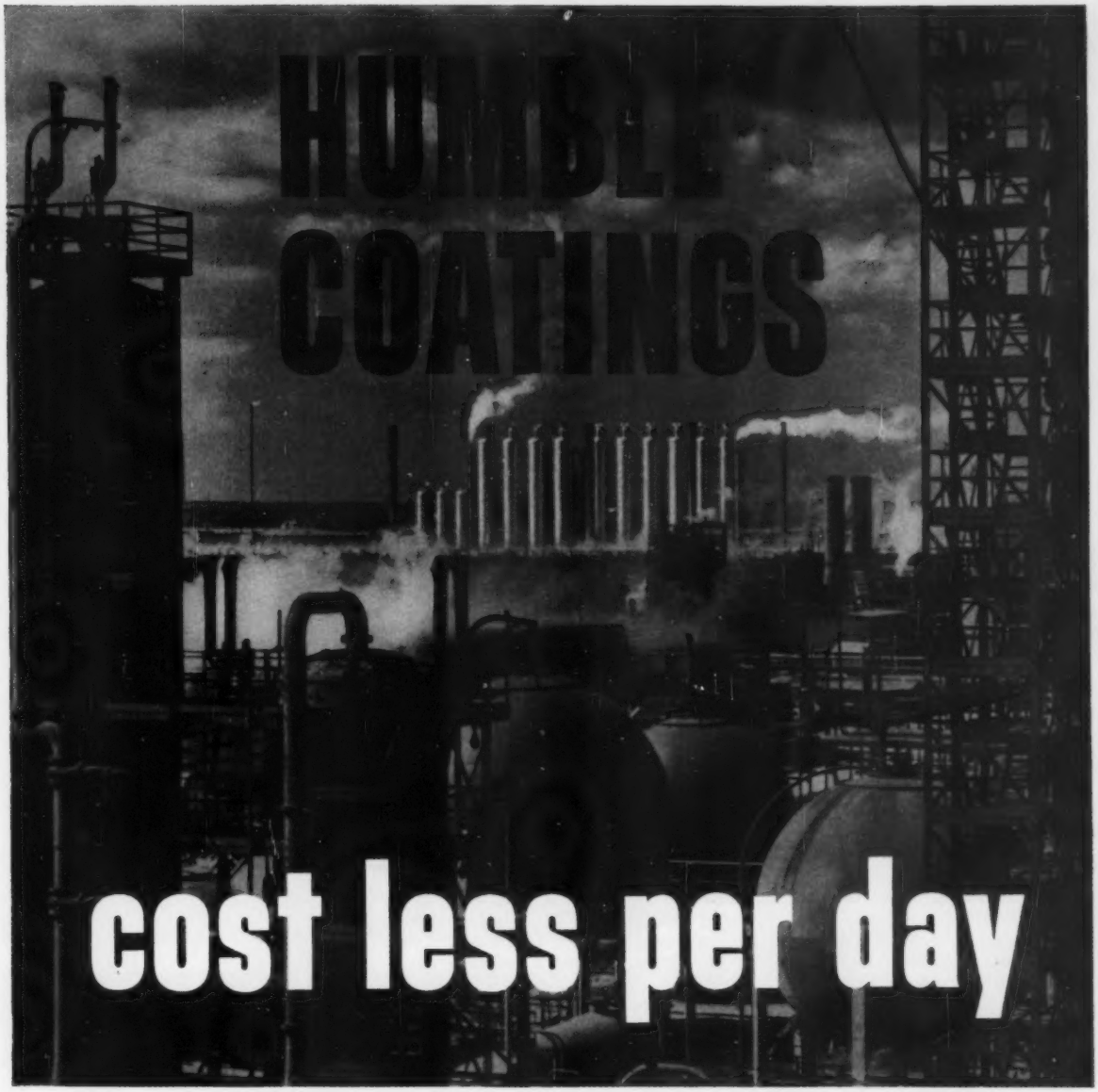
Since 1843

The Eagle-Picher Company
Dept. PR 660
General Offices: Cincinnati 1, Ohio

Here's why you save money when you use Eagle-Picher Super "66" Insulating Cement

- Because it sticks, Super "66" saves time — applies quickly to any equipment, cold or hot. Effective up to 1800°F. . . . and it contains a special rust inhibitive which actually prevents corrosion !
- Because it sticks, Super "66" saves money— provides far greater coverage and more efficient insulation.
- Because it sticks, Super "66" makes difficult jobs easy—can be used on irregular shapes where application of other insulations is often impossible. Usually requires no reinforcing on applications up to 1½ inches thick.

For more data on advertised products, use Readers' Service Cards, last page.



Humble paints and protective coatings last longer — extend the interval between your repaints by six months to a year. Fewer paint jobs mean savings on paint and labor. Cost per day is that much less.

But this is your big saving: Humble coatings give you better protection — they pay off in longer life for expensive equipment.

Developed to give maximum protection under the severe corrosive conditions in refineries and chemical plants, these continuously improved coatings have been profitably used by industry for over 25 years.

For more information on Humble's complete line of paints and protective coatings call your Humble salesman, or contact Humble Oil & Refining Company, Houston, Texas.

HUMBLE

HUMBLE OIL & REFINING CO.

For more data on advertised products, use Readers' Service Cards, last page.

WHADAYA MEAN "OR EQUAL"?

UNIBESTOS... No-Shrink, No-Shock!

No matter how carefully specifications are worked out, the term "*or equal*" can mean trouble . . . big trouble. Take insulation shrinkage and shock for example. Hard to predict, hard to account for, they mean heat loss and replacement that can put a serious crimp in any profit picture.

That's the very reason why Unibestos "*no-shrink*," "*no-shock*" insulation is worth more to you. Yet it sells at competitive prices. Prove to yourself how Unibestos saves you money by eliminating shrinkage, breakage, and thermal shock. See how it defies fumes, acids and moisture; cuts application time and cost, and guarantees real insulating efficiency.

Available in a full range of standard pipe sizes and in block form. Single thicknesses to five inches. Specials to 44" O.D. in half sections.

Write today, on your letterhead, for Bulletin No. 65610.

UNIBESTOS AMOSITE INSULATION

EFFECTS OF THERMAL SHOCK

Exclusive use of extra long ***Amosite*** asbestos is your positive assurance that Unibestos insulation has the mechanical qualities that prevent thermal shock effects. Guaranteed up to 1200° F. Unibestos has been known to withstand temperatures as high as 2000° F. without thermal shock effects.

UNIBESTOS

worth more, yet sold at competitive prices

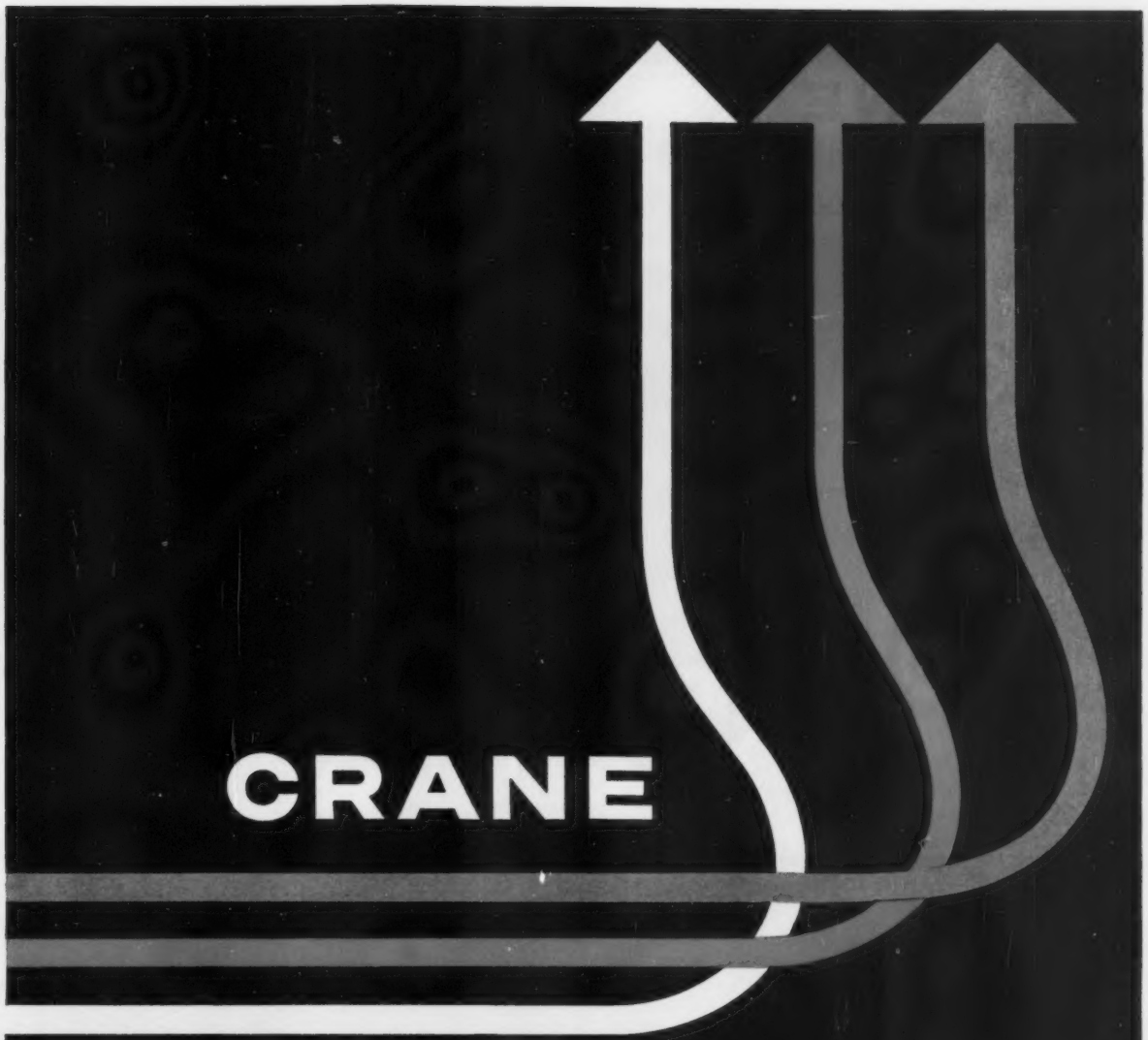
UNARCO®

UNARCO PRODUCTS

• UNIBESTOS, Amosite Asbestos Pipe Covering and Block • Calcium Silicate Pipe Covering and Block • 85% Magnesia Pipe Covering and Block • Mineral Fiber Block • Wrap-On Insulation • Lace-On Insulation • Turbine Blankets • Insulating and Finishing Cements • Asbestos Textiles • Packing and Gasketing.

UNION ASBESTOS AND RUBBER COMPANY • FIBROUS PRODUCTS DIVISION

DEPT. 262, Bloomington, Illinois



DIRECTION '70

A FAST-MOVING PROGRAM OF EXPANSION, PRODUCT DEVELOPMENT AND STREAMLINED DISTRIBUTION TO HELP OUR CUSTOMERS MEET THE CHALLENGE OF THE SOARING SIXTIES

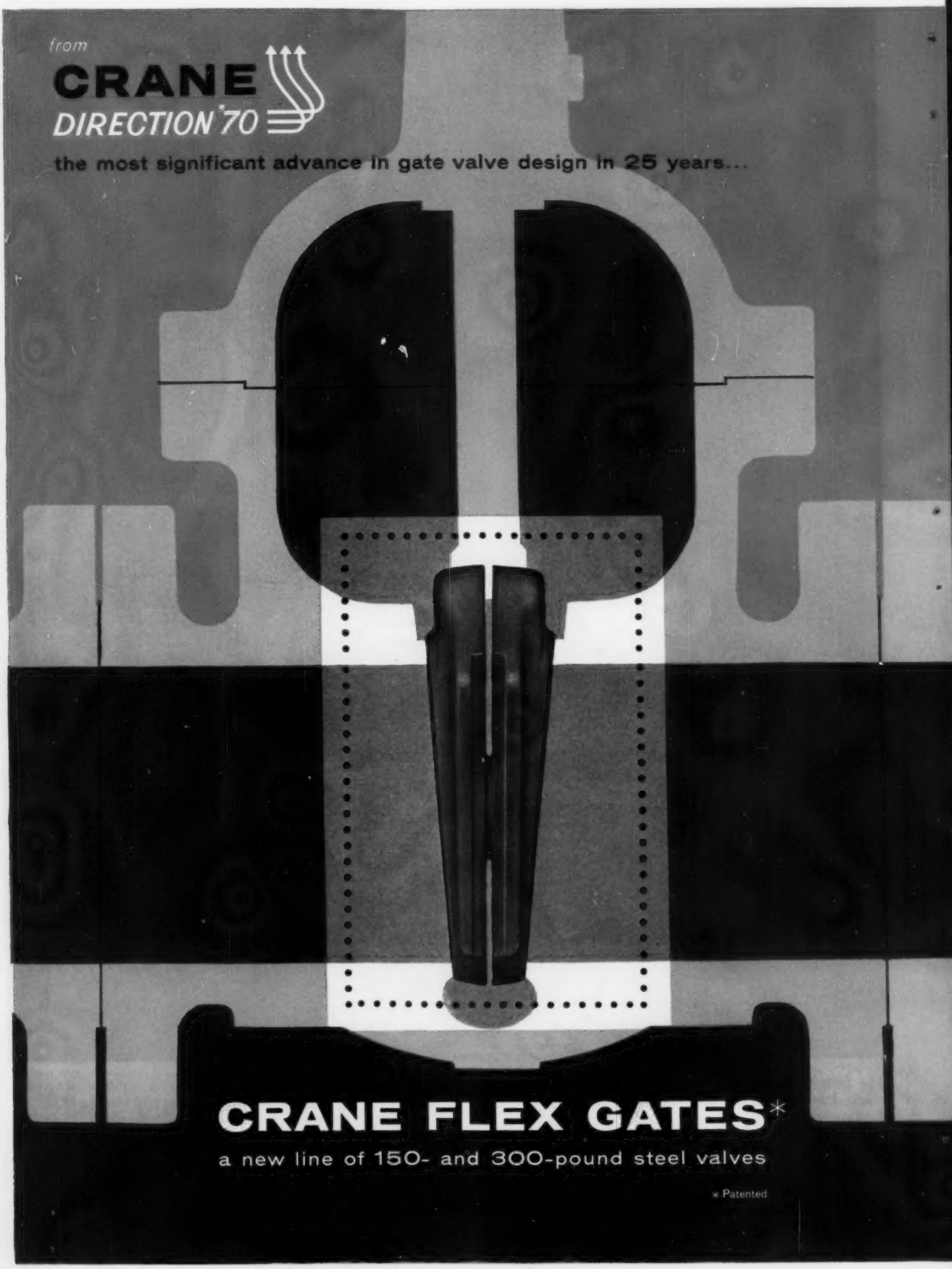
The Soaring Sixties have begun. This is the decade to be marked by accelerated industrial growth. By 1970, predictions are that . . .

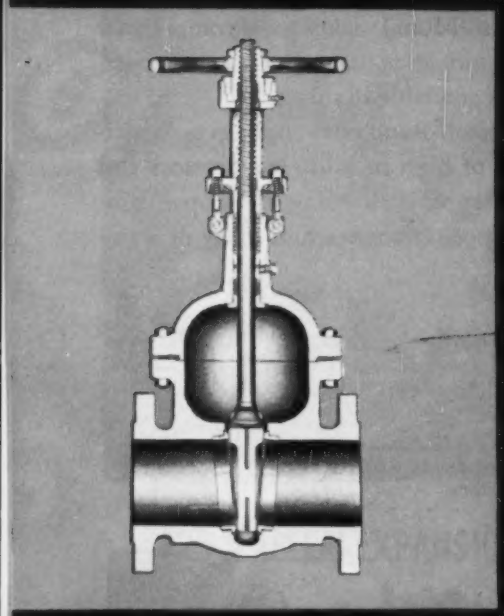
- machinery production will double
- petroleum production will increase 4% to 5% each year
- chemicals are to double their present output at the current compound growth rate
- food processing will rise nearly 40%, paper and allied industries will expand about 60%

Total industrial production is estimated to rise some 60% in the next ten years. Looking at it another way, the prospective *increase* in manufacturing and mining is almost as large as the total output of just 12 years ago.

Crane announces Direction '70 . . . new products to help industry meet the challenge of the Soaring Sixties. These are products to improve quality control. These are products to increase production. These are products to help you control your costs. On the following pages is the first . . . the most significant Gate Valve improvement in 25 years. It's the first announcement of many you'll be seeing from Crane in Direction '70.

For more data on advertised products, use Readers' Service Cards, last page.


from
CRANE
DIRECTION 70
the most significant advance in gate valve design in 25 years...
CRANE FLEX GATES*
a new line of 150- and 300-pound steel valves
* Patented



Instead of being made with a solid disc, new Crane Flex Gates have separate disc faces, connected by the spool-like unit you see in the cross section. This joins the two seating faces, yet provides flexibility for the faces to seat tightly with independent action.

FLEXIBILITY PROVIDES THESE BENEFITS

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates seat with less torque.

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates unseat with less torque . . . will not stick closed even in high temperature service.

BECAUSE THEY'RE FLEXIBLE, minor deflection of seating faces due to pipe strains does not affect tightness of Crane Flex Gates.

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates are tight on inlet seat and outlet seat over a wide range of pressures.

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates can be used singly in some services where two conventional gate valves are frequently specified. You can save substantially on piping costs. And they have been exhaustively field tested.

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates can be serviced—body seat rings replaced or seating faces refinished—quickly without painstaking accuracy. Slightly off-taper seats do not affect tightness or operating ease.

BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates will easily outperform any conventional solid wedge disc valve you now use. *And there's no increase in price.*

BECAUSE THEY'RE MADE BY CRANE, these new Flex Gates are completely dependable. You can use them with complete confidence on steam, water, gas, oil or oil vapor service. Stem and disc seating faces are Crane Exelloy. Shoulder-type body seat rings are Exelloy or Crane No. 49 Nickel Alloy. Sizes 12 inch and smaller; 150- and 300-pound pressure classes.

• • • • •

Ask your nearby Crane Distributor for full information on Flex Gates—and for data whenever you work with the products Crane makes. He has the newest in information *and* products. Crane Co., Industrial Products Group, 4100 South Kedzie Avenue, Chicago 32, Illinois.

CRANE®

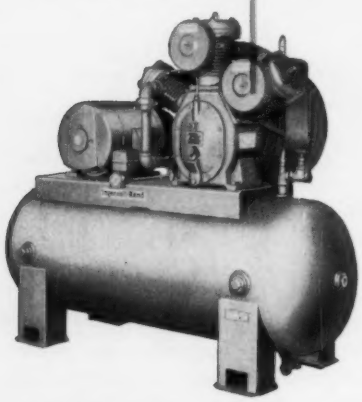
VALVES • ELECTRONIC CONTROLS • PIPING
PLUMBING • HEATING • AIR CONDITIONING

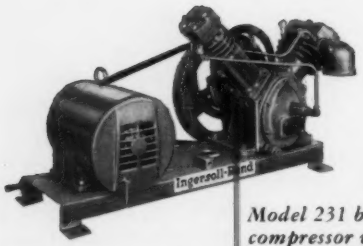
For more data on advertised products, use Readers' Service Cards, last page.

high pressure COMPRESSED AIR

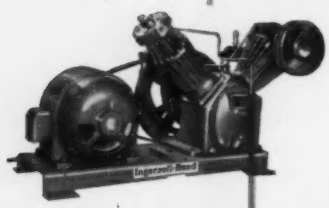
...in small quantities from small air-cooled compressors

Model H15TE tank mounted compressor will deliver air at 250 psig pressure.





Model 231 baseplate mounted compressor will deliver air at 500 psig pressure.



Model 41 baseplate mounted compressor will deliver air at 1000 psig pressure.

1½ through 25 horsepower
250 to 5000 psig pressure

For air blast circuit breaking, air starting of engines, valve test stands, accumulator service, oil field rigs, air craft support equipment, etc., Ingersoll-Rand can supply compressors, off the shelf, specifically designed for high pressure operations.

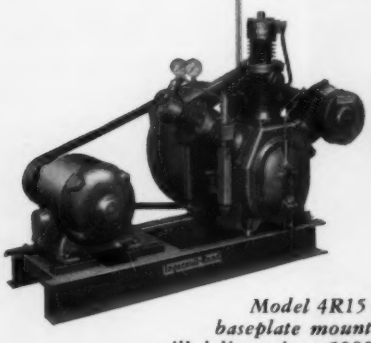
Proper selection of high pressure compressors is important. Duty cycle, minimum and maximum running time and intended maintenance are all important factors. Ingersoll-Rand makes these compressors to give you exceptional value in a most compact, economical and dependable design.

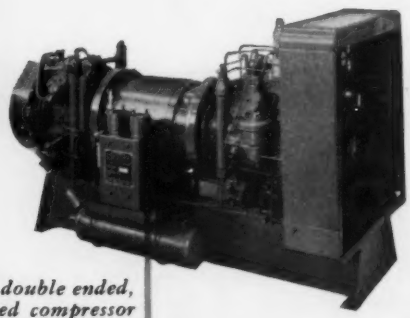
Your local Ingersoll-Rand sales engineer is experienced in the field of high pressure compressors and is prepared to assist you in choosing the proper compressor for your application. See him today or write to—

Ingersoll-Rand

85A3 **11 Broadway, New York 4, N. Y.**

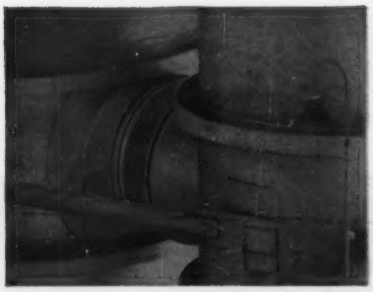
Model 15T3 baseplate mounted compressor will deliver air at 3000 psig pressure.



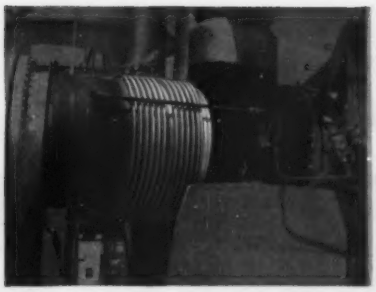


Model 4R15 double ended, baseplate mounted compressor will deliver air at 5000 psig pressure.

OTHER I-R HIGH PRESSURE COMPRESSORS TO 7500 HP-PRESSURES TO 35000 PSIG

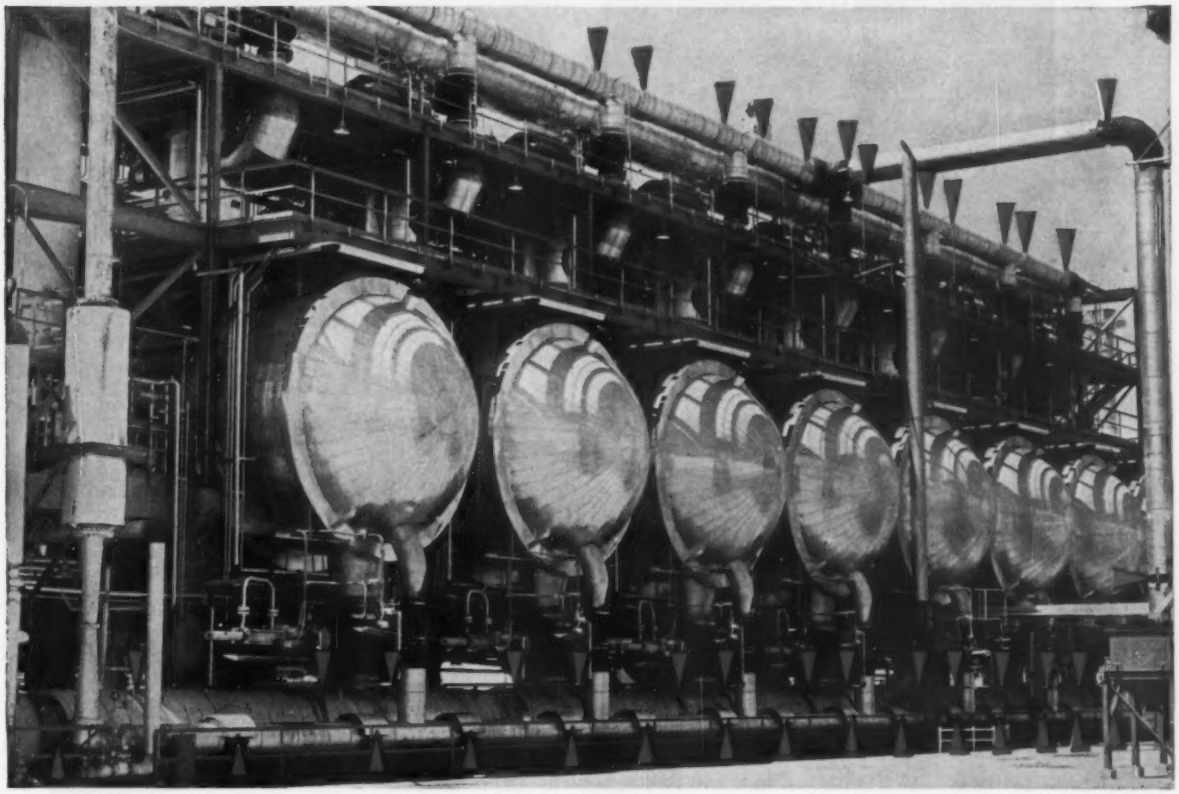


85½ in. dia. expansion joint connecting quench and pre-quench towers. Pinned structural ties permit expansion joint to absorb axial and differential vertical movement.



48 in. dia. expansion joint at compressor discharge. Double bellows permit large axial movement. Internal sleeve guide provides for stability, minimum pressure drop.

54 in. dia. hinged expansion joints in loop to pre-quench tower. They absorb 5⅜ in. vertical expansion and 7⅞ in. horizontal expansion due to 1200°F temperature in reactor header.



125 ZALLEA EXPANSION JOINTS, 125 demands for maximum reliability

Expansion joints, specially engineered and designed by Zallea, solve problems of space, heat and flow for Odessa Butadiene Co., Odessa, Texas.

Large-diameter piping (up to 72 in. dia.), with short, straight runs and critical flow conditions, posed new design problems. High temperature operation (1200°F) required minimum loading on sensitive equipment. Open-air construction, with few load carrying members dictated maximum stability of expansion joints with minimum use of external guides and anchors to support pipe weight and resist wind loading.

To solve these problems called for a competent, close-working team of process, piping and structural engineers from Fluor Corp. Ltd., design engineers from Odessa Butadiene Co., and application engineers from Zallea.

Result: A compact, reliable piping-expansion joint system that permitted containment of an efficient, 50,000 ton per year unit in an area whose largest dimension is a few hundred feet.

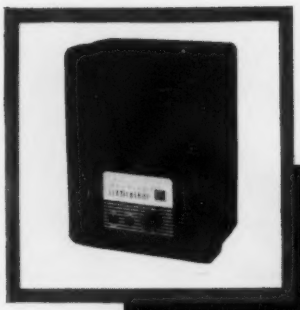
This is another example of how Zallea experience in handling critical, complex Expansion Joint applications can save time and money. For more facts, call us . . . or write for catalog 56.

ZALLEA BROTHERS, Taylor and Locust Sts., Wilmington 99, Del.

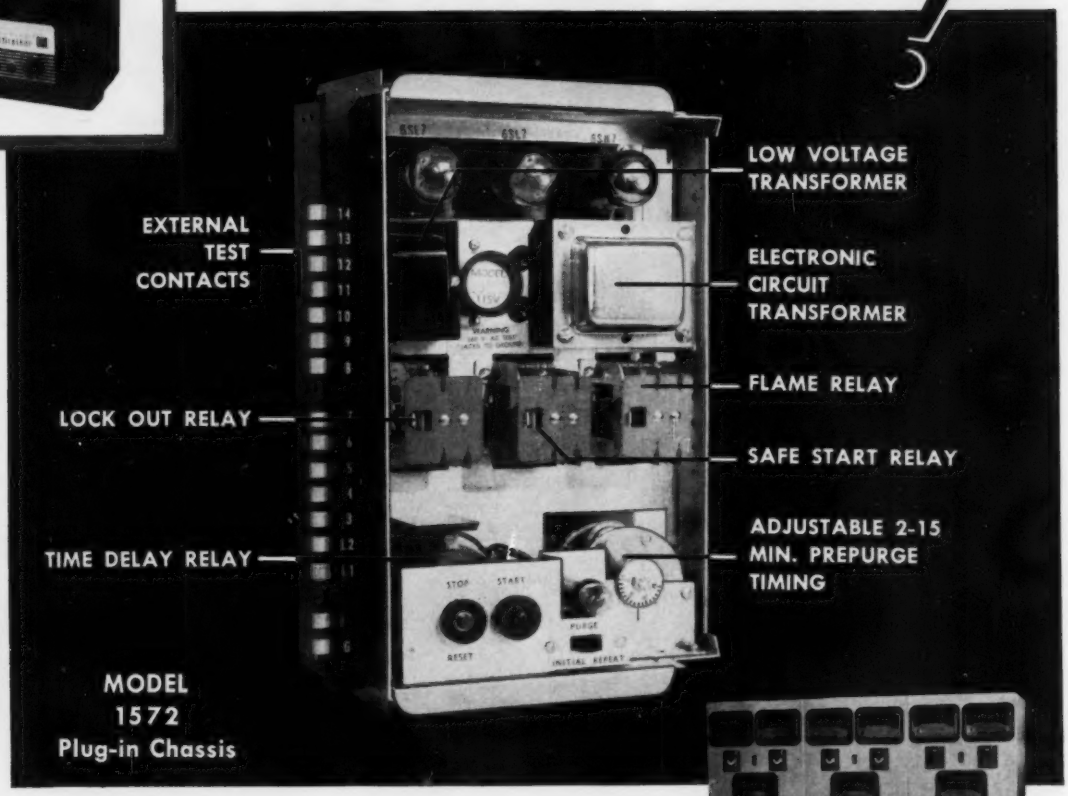
Zallea **FOR MAXIMUM RELIABILITY**

WORLD'S LARGEST MANUFACTURERS OF EXPANSION JOINTS

For more data on advertised products, use Readers' Service Cards, last page.

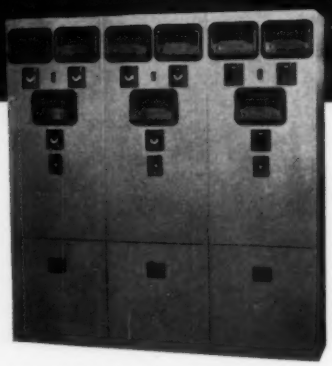


Fire when ready



Automatic Safe-Starts with Wheelco Flame-otrols

Dependable Wheelco Flame-otrols monitor gas, oil or combination flames . . . in small or large furnaces, boilers, kilns and dryers . . . with automatic "flame-out" protection, programmed purging, warm-up proving, pilot proving, and ignition timing. Semi-automatic or manual operation is available. Wheelco Flame-otrols have easy-servicing plug-in chassis, heavy-duty construction, printed circuit boards, standard electronic tubes and external test contacts. *All contacts are visible and accessible during programming.* Your nearby Wheelco office has field-experienced engineers ready to help you . . . call them anytime.



WHEELCO CONTROL CENTERS — Wheelco designs, assembles and prewires control centers to contain all systems for control, indication, recording and alarms . . . for programming all combustion phases (above) . . . or simple flame-off manual-start (below).

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments Division

BARBER-COLMAN COMPANY

Dept. F, 1597 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. F, Toronto & Montreal • Export Agent: Ad. Auriema, Inc., N.Y.

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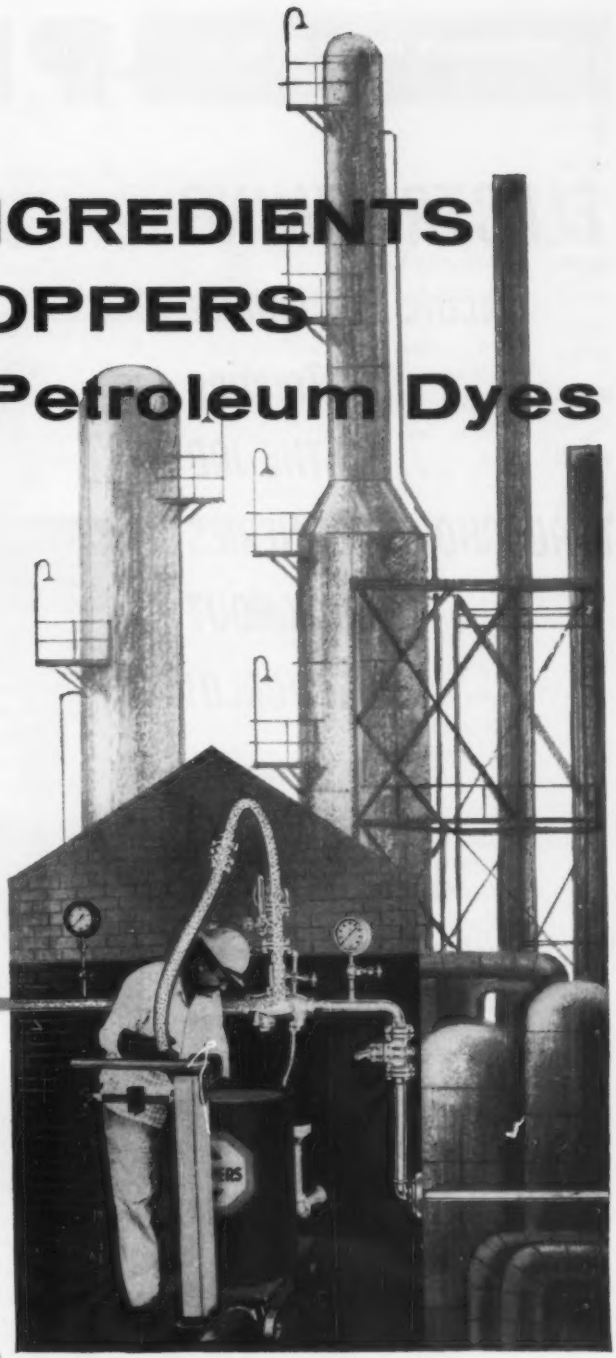
PLUS INGREDIENTS in KOPPERS Gran-U-Flow™ Petroleum Dyes



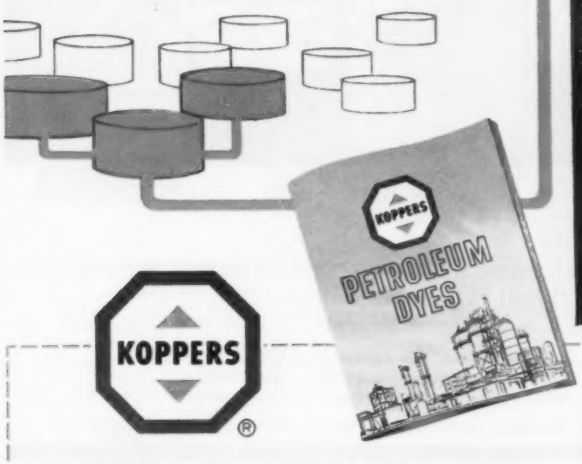
There *are* PLUS INGREDIENTS . . . in Koppers Gran-U-Flow Dyes . . . extra reasons why you should specify Koppers:

- unvarying uniformity . . . batch-to-batch
- high tinctorial strength
- dustless
- low benzene insolubles
- high solubility
- granular (Gran-U-Flow) . . . for *easy* flow

Whether you use petroleum dyes for gasoline, anti-freeze or a wide range of lubricants . . . for corporate identity, improvement of product appearance or ease of identification . . . you owe it to yourself to investigate the superior advantages of Koppers Gran-U-Flow Dyes.

Dye drums are color coded and designed for eductor systems in refineries.

Clip the coupon below to your company letterhead for a booklet showing newest eductor techniques. A free laboratory kit is also available. VMA 6982



KOPPERS®

KOPPERS COMPANY, INC.

Chemicals and Dyestuffs Division

KOPPERS BUILDING, PITTSBURGH 19, PA. • **Plant:** Lock Haven, Pa.
Branches: Providence, R. I. • Philadelphia, Pa. • Paterson, N. J. • Chicago, Ill. Charlotte, N. C. • Chattanooga, Tenn. • Columbus, Ga. • Los Angeles, Calif. Houston, Texas • **Dominion Anilines & Chemicals, Ltd.,** Toronto, Canada

☐ Please send booklet on newest eductor techniques.

☐ Please send free laboratory kit for Gran-U-Flow Petroleum Dyes.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

CLIP TO YOUR COMPANY LETTERHEAD.
Mail to our Pittsburgh office or nearest branch.

For more data on advertised products, use Readers' Service Cards, last page.

PRODUCT IMPROVEMENT WITH **PETRECO**

ELECTROFINING

Electric Precipitator Treating ...ON THE JOB THROUGHOUT REFINERIES ...THROUGHOUT THE WORLD!

DO YOU HAVE ONE OF THESE TREATING PROBLEMS?

(Successfully Treated the ELECTROFINING Way!)

If you have a treating problem, ELECTROFINING* Electric Precipitator Treating might well provide the answer. It has, for refineries all over the world—in improving and stabilizing streams from many different types of refining units.

The table shown here lists some of the places in which ELECTROFINING units are successfully being used, some of the stocks being treated, some of the treatments applied and some of the product improvements gained by the process.

It is equally important to note that the ELECTROFINING process permits intimate and instantaneous contact between hydrocarbon and chemical treating agents, assuring immediate separation with minimum carry-over or effluent pollution. The process is precise, automatic and continuous.

ELECTROFINING PRECIPITATORS USED WITH THESE UNITS	PRODUCT STREAMS TREATED	TYPE OF TREATMENT	PRODUCT IMPROVEMENT
Crude Distillation	S. R. Gasoline	Water Removal	Gum Reduction
Thermal Cracking	Cat. Gasoline	Water Wash	Sweetening
Catalytic Cracking	Diesel Fuel	Caustic Wash	RSH Removal
Vacuum Flashing	Jet Fuel	Acid Treat	Organic Acid Removal
Hydrotreating	Kerosine	Acid-Caustic	Olefins Removal
Reforming	Cat. Cycle Oil	Caustic-Water	Color Improvement
Alkylation	Lube Distillates	Doctor Treat	Improvement of Viscosity Index
	Cracked Fuels	Sulfonation	Sedimentation Prevention
	Virgin Gas Oil		
Detergent Alkylation	Heavy Cat. Gaso.	Acid Precipitation	Color Stabilization
	Alkylation Products	Caustic-Sodium	Savings in Product
	S. R. Naphtha	Sulfite Treat	Haze Prevention
	No. 1 Fuel		Savings in Treating Chemicals
	No. 2 Fuel		Odor Improvement
	SO_2 Raffinate		Pollution Prevention
	SO_2 Extract		Sodium Ion Removal
	Coker Naphtha		Nitrogen Removal
	Spray Oils		Arsenic Removal
	Poly Gasoline		Naphthenic Acid Removal
	Benzine Alkylate		Tarry Acid Removal
	Re-refined Lube		Thiophene Removal
	Hydrofined Varsol		
	Hydrofined Sour Gas Oil		

GET THE COMPLETE ELECTROFINING STORY from your local PETRECO Engineer, or write to . . .

DT-60-3

*Registered trademark of Petrolite Corporation

PETROLITE CORPORATION

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1390 East Burnett Street (P.O. Box 7216), Long Beach 7, California

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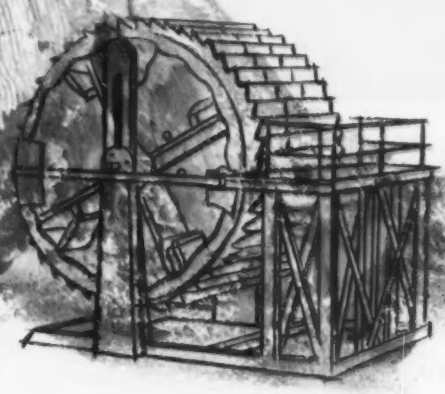
NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague
TRINIDAD: Neal and Massy, Ltd., P. O. Box 544, Port of Spain

THE QUALITY OF THINKING

From an almost unlimited scope of thought, Leonardo da Vinci brought forth a stream of inventions which — in modern form — are in use today. However, Leonardo's greatest contribution was simply the triumph of creative thought applied to practical results. His work will stand for all time as proof that the appraisal of quality applies to thinking as well as to tangible objects and to visible or audible processes.

In a related sense, the quality of engineering is measured by results. And it is by results alone that the minds responsible for an engineering project can be evaluated. When you check the record of Brown & Root's engineering through the years, the high quality of thinking is self-evident. Customer satisfaction from greater efficiency at lower costs has built a worldwide reputation for engineering and construction by Brown & Root.



This squirrel-cage blower, invented by Leonardo da Vinci and put to practical use, was a significant step toward modern mechanical air conditioning.

BROWN & ROOT, INC.

Engineers · Constructors

POST OFFICE BOX 3, HOUSTON 1, TEXAS

NEW YORK • WASHINGTON • LONDON • EDMONTON • MONTREAL
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Inside plants and refineries:

What can you do about moisture, oil or corrosives that attack your wiring?

One refinery actually tested the corrosion resistance of building wire *on the job:*

Regular TW . . . neoprene-covered . . . braided rubber-insulated . . . lead-covered . . . and *Rome Synthinol 901!*

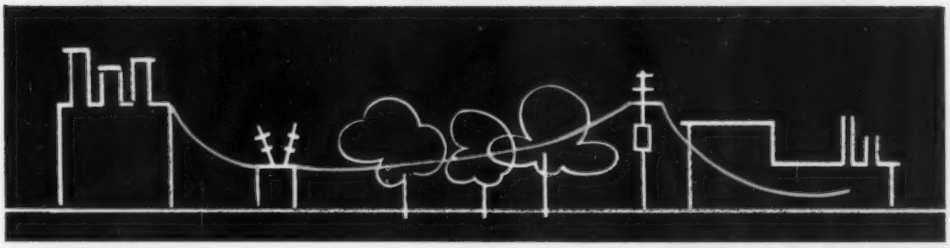
RESULT: Only Synthinol 901 and the lead-covered wire held up under exposure to corrosives.

BEST BUY: Rome Synthinol—lower in cost and easier to handle than lead-covered wire.

Synthinol 901 has been proved in the lab and on the job for its resistance to moisture, oil and corrosive vapors. You can recommend it to your industrial customers for any low-voltage application—600 volts and under—including control circuits, plant and refinery equipment, and general wiring of office and warehouse buildings.

Where higher than normal heat conditions exist, you can recommend Synthinol 901 for its superior heat-deformation resistance. You can even use it to replace varnished cambric insulation on oil-filled transformer leads, where the leads are constantly immersed in hot oil.

Get further information, including lab test results, on Rome Synthinol 901—yours for the asking from Rome. Just clip the coupon, mail it today!



Power source to plant—Rome Cable gives you the *right* answer to every wiring problem. Power station to substation: Rome's interlocked armored cable "installs like cable, protects like conduit." Substation to plant or refinery: Rome's preassembled aerial cable goes up fast—even through trees—and is well protected from storms. Inside plant or refinery: Rome Synthinol gives maximum corrosion resistance, assures dependable service.

ROME CABLE
DIVISION OF **ALCOA**

Department 19-60, Rome, N. Y.

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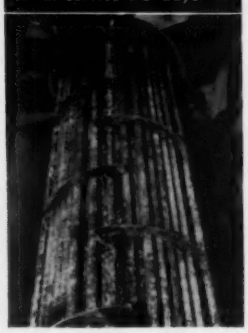
ALCOA
ROME CABLE
DIVISION

another
TRETOLITE SERVICE
report

Midwestern refinery "saves a bundle" with KONTOL* *Corrosion Inhibitor*



Before KONTOL treatment, —in service 76 days

After 295 days' service, with KONTOL treatment

Both ways—in dollars and in actual equipment—this refinery "saved a bundle" in its crude unit heat exchange section by adopting a KONTOL* protection program.

Heat exchange was inefficient and tube life was short. Then KONTOL Corrosion Inhibitor was injected into the overhead line ahead of the condensers.

Here are the bundle-saving results:

- Tube bundle life was *tripled* by drastic curtailment of corrosion.
- Heat savings amounted to *6,000,000 BTU's per hour*, as a result of KONTOL's powerful detergent action.
- Estimated cost of heat loss was $96 per day prior to use of KONTOL. KONTOL protection eliminated this loss for only $20 per day—a savings of nearly 5 times the cost.

KONTOL Corrosion Inhibitors are protecting tube bundles, and saving bundles of money, for refiners all over the world. Ask your Tretolite Field Service Engineer (the "Man in the Red Car") for more details.

*Registered trademark of Petrolite Corporation

KR-60-5

PETROLITE CORPORATION

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5515 Telegraph Road, Los Angeles 22, California

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ENGLAND: Petrolite Limited, 20 Savile Row, London W.1
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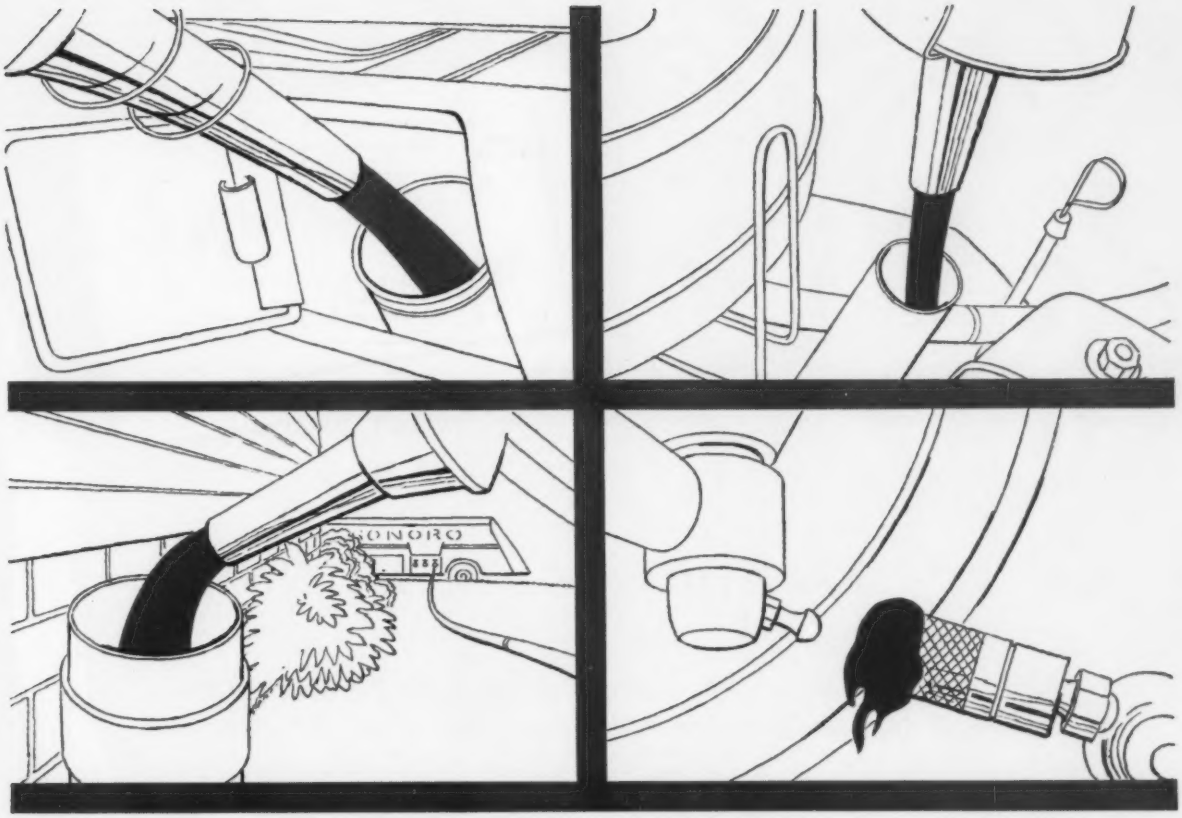

RAINBOW FOR SALE... with new finer-flaked Du Pont dyes

Du Pont petroleum dyes provide sales appeal for your products more efficiently than ever before

Because flaked dyes are virtually dust-free, they are constantly gaining in popularity. Today they're becoming the standard material for dyeing gasoline as well as adding sales appeal to other petroleum products—kerosine, home-heating oils, tractor and diesel fuels, lubricating oils and greases.

Now . . . faster dissolving. The new finer-flaked Du Pont dyes now dissolve more rapidly than ever. As a result, more and more refiners are finding they can take advantage of the dust-free properties of Du Pont flaked dyes.

Lower handling costs. The new flaked form of Du Pont petroleum dyes makes them free-flowing and easier to handle than powders. They are more compact, take up approximately half the space of conventional powdered dyes. Drum height has been reduced to 22 inches. This, too, makes handling easier and faster, as well as saving valuable storage space for the refiner.

Many colors. You can get these finer-flaked Du Pont dyes in orange, red and bronze. (Blue dye is available in a crystalline form which has the same advantages as flaked dyes.) Samples and full details are available from your Du Pont Petroleum Chemicals representative. Or write to E. I. du Pont de Nemours & Co. (Inc.), Petroleum Chemicals Division, Wilmington 98, Delaware.

DU PONT

Better Things for Better Living
. . . through Chemistry

Tetraethyl Lead
and other
Petroleum Additives

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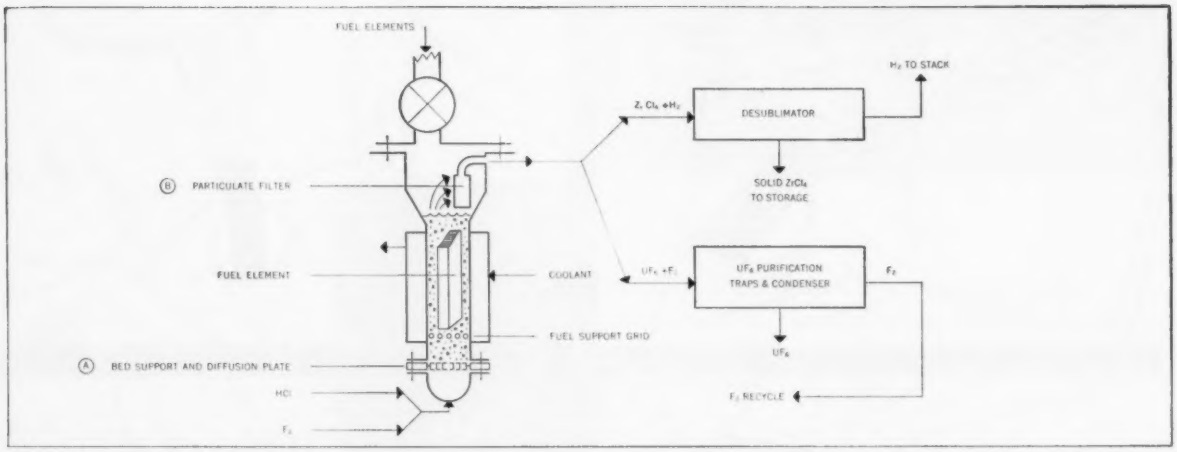

$$Zr + 4HCl \rightarrow ZrCl_4 + 2H_2$$
$$U + 3F_2 \rightarrow UF_6$$

. . . and it wouldn't be possible without the Purolator filter that helps cut nuclear fuel reprocessing time from 24 hours to 1½

The latest achievement in reducing the prohibitive fuel-cycle costs of nuclear energy is a fluidized bed halogenation process that provides clean separation of uranium from a zirconium-uranium fuel element. This new process, a big improvement on conventional gas phase volatility processes, was developed at Brookhaven National Laboratory. It would not be operable without two Purolator developments: an Inconel metal-edge distributor plate, A, which is faced on both sides with porous metal; and an Inconel frameless metal edge filter, B, which is faced on the outside with porous metal.

The principal advantage of the fluidized bed technique is its speed in recovering uranium from spent fuel elements. The standard gas phase process takes 24 hours; with a fluidized bed, recovery time is cut to 1½ hours, and the reaction is more uniform and more easily controlled, too.

To operate the Brookhaven pilot plant, a 10" section of spent fuel element is submerged in a mass of inert granular material that is suspended in a mobile, or fluidized, state, by introducing hydrogen chloride gas at suitable velocity at the bottom of the reactor vessel. The Purolator-designed diffuser plate assures complete dispersion of the HCl through the granular bed. Inconel, a porous metal, is used to face the top and bottom surfaces of the plate, to resist the corrosion and the reaction temperature of the fluidized bed, which ranges from 400-450°C.

By creating a reaction in a fluidized bed, coefficients of heat transfer as high as 400 Btu/Hr x Ft² x °F have been observed, with corresponding reaction rates up to 6000 mg per cm²/hr, much higher than could be achieved if gas were the sole coolant. The upward velocity of the gas required to sustain the bed in a fluidized state tends to raise minute particles of uranium above the bed. The metal-edge Purolator filter effectively screens these particles to prevent their loss. The filter that Purolator designed for the Brookhaven installation is composed of a continuous Inconel spiral with integral risers, coated with a thin facing of Inconel which ensures an average filtration of 1 micron.

Performance to date has been so successful that the Brookhaven team plans to build a pilot plant halogenator to conduct complete hydrochlorination and fluorination reactions on full-scale fuel elements. The full-scale production unit will incorporate six Purolator Inconel filters. In addition, because of its corrosion resistance, Inconel will be used as construction material for the halogenator vessel, instead of the present stainless steel.

Presumably you don't have the problem we've just described, but it is a good case in point that Purolator can filter anything that flows. And if your problem (whatever it is) could conceivably involve a filter or a separator, Purolator can help you. Our address: Purolator Products, Inc., Dept. 2683, Rahway, New Jersey.

Filtration for Every Known Fluid **PUROLATOR**

PRODUCTS, INC.

RAHWAY, NEW JERSEY, AND TORONTO, ONTARIO, CANADA

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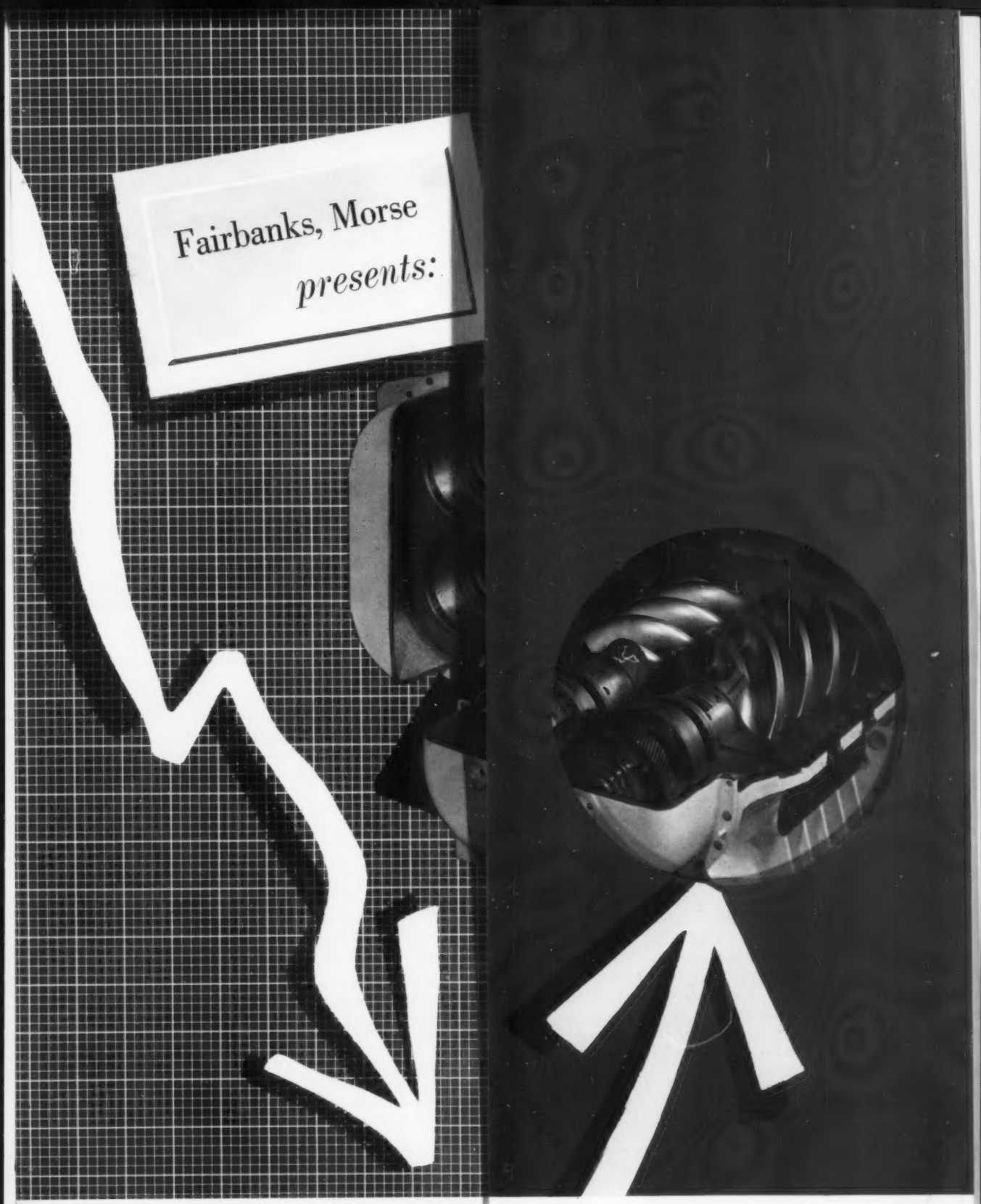


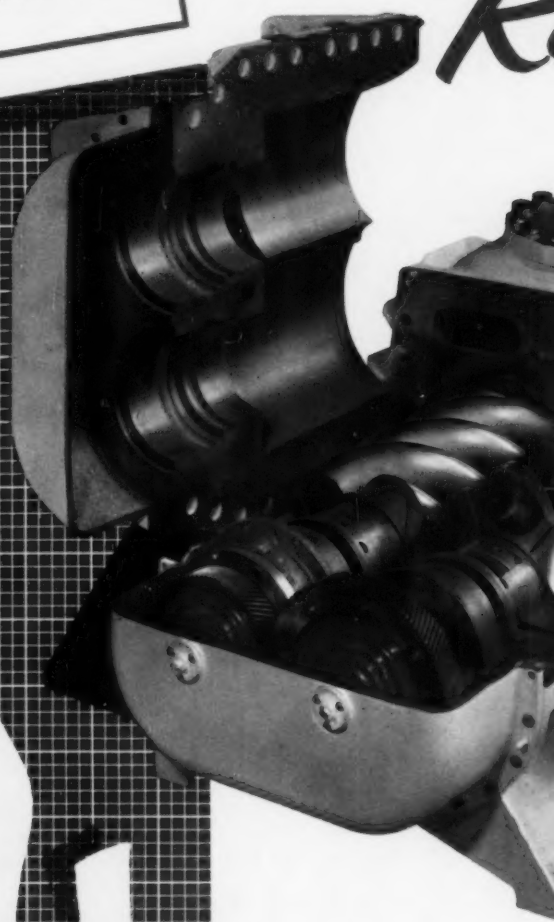
A Proved Way to Prevent "Production Downtime!"

Fairbanks, Morse
presents:

the amazi

F-M HEA

R



Fewer wearing parts mean
Freedom from Shutdowns!

- Rotors revolve without touching each other . . . or housing walls! . . . Vital parts and efficiency are maintained!
- It's S-M-O-O-T-H . . . no loosening of foundations or connections!
- Combines the best of both centrifugal and reciprocating compressors.

A Proved Way to Prevent Mechanical Bre

F-M HEAVY-DUTY COMPRESSORS HAVE

zing

AVY DUTY

Rotary Compressor

- *Capacity up to 20,000 CFM*
- *Compression ratios up to 5:1 per stage*

Oil Free Delivery! High Efficiency* Compression with low HP *reduces Operation Costs!

- The F-M Heavy Duty Compressor uses less horsepower to achieve compression ratios up to 5:1 per stage than either a centrifugal or other available rotary compressors!
- *Care-Free* F-M Compressor requires no internal lubrication . . . provides *Oil-Free* compression.

It's Compact . . . uses less floor space!

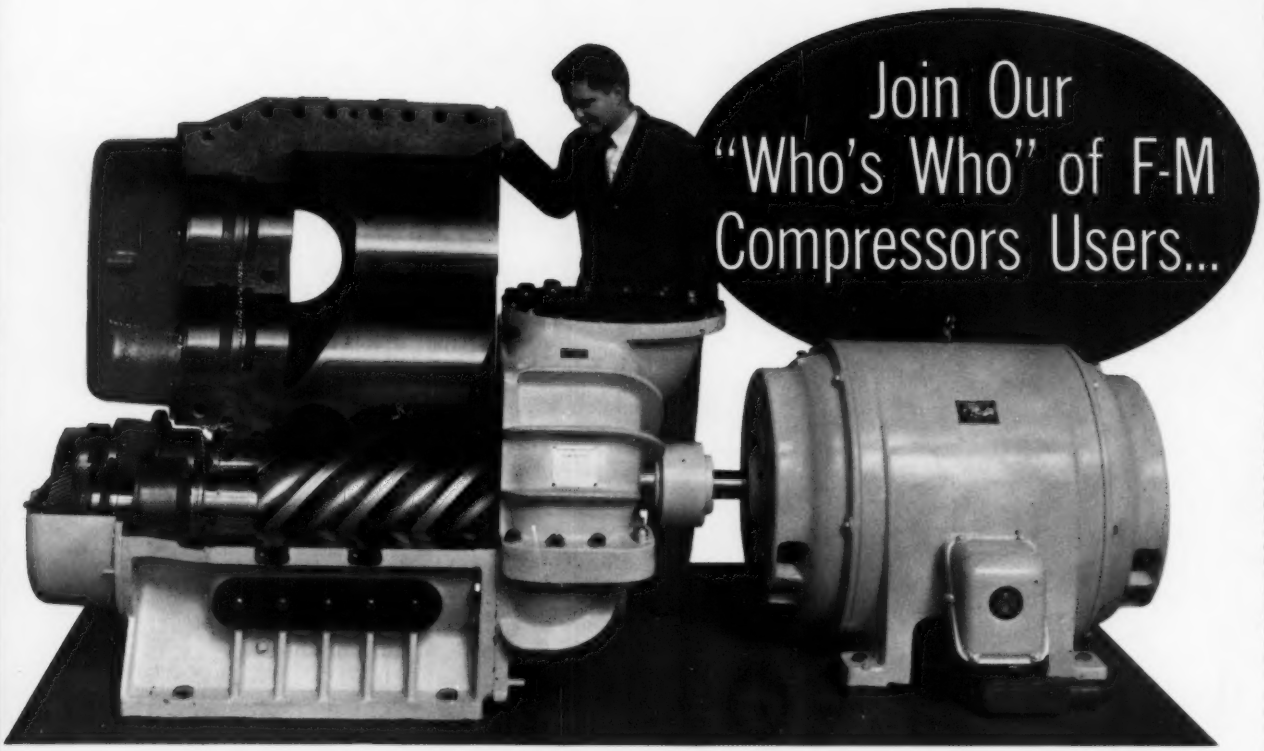
- Other compressors cost *more* because of increased installation and maintenance costs!
- F-M's heavy duty compressor weighs less . . . uses lower cost foundations.
- Less floor space increases your plant operating efficiencies.

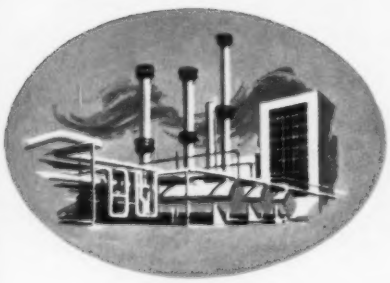
F-M's Compressor is surge-free because of *Positive Action Design!* No pistons, valves, reciprocating parts!

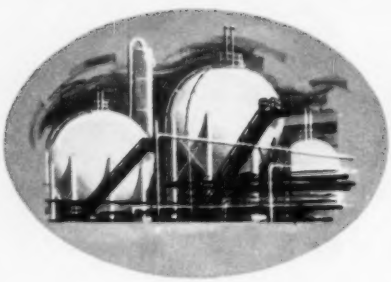
- Helical shaped rotors compress air or gas smoothly with high over-all economy.
- Axial compression occurs with the meshing of the male rotor lobes and the female rotor lobes. Discharge of compressed air or gas from successive interlobal cavities overlap resulting in *steady delivery, minimum vibration.*

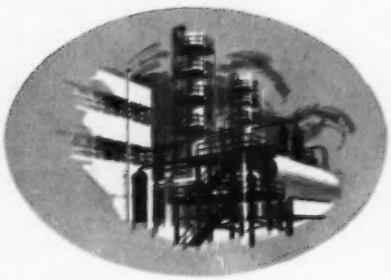
reakdowns and Shutdowns!

HAVE BEEN THOROUGHLY PROVED IN MAJOR INDUSTRIAL INSTALLATIONS . . HERE AND ABROAD **PLEASE TURN PAGE**









Orders filled or at hand for the unique Fairbanks, Morse Rotary Compressor read like a "Who's Who" of world-wide industry. You'll recognize them instantly! We'll make the list available on request.

Only F-M's Rotary Compressor gives you . . .

Continuous trouble free operation. • Less wear. • Fewer replacements. • Smooth, surge-free compression. • Highest efficiency of any rotating compressor. • Minimum floor space requirements. • Oil-free compression. • Minimum foundation costs. • No pistons, valves, reciprocating parts to wear. • No metal-to-metal contact in compression chamber. • No internal lubrication. • Pressure, vacuum or combination operation. • Minimum vibration, fewer repairs. • Less costly to install, operate and maintain. • Maximum mechanical simplicity. • Adaptable as portable or skid type unit. • High compression ratios.

The F-M Compressor . . . a *Versatile Asset* to Any Operation! F-M Rotary Compressors are available as single-stage units ranging in capacities from 800 to 20,000 cfm, for compression ratios from 1.6:1 to 5.0:1. Also for multi-stage or booster service at maximum working pressures up to 250 psig.

The F-M Compressor . . . a *Valuable Asset* to Any Operation! Chemical Processors—manufacturers of ammonia, ammonium nitrate, hydrogen peroxide, chlorine, ethylene, butadiene, acids, phenol, formaldehyde, and other chemical products requiring the compression of air or gas.

General Uses . . . Pressure and vacuum systems, process refrigeration, gas and vapor recycle service, production of yeast, tonnage oxygen, fertilizer. Catalytic cracking operations, fermentation processes, vapor recovery systems, aeration and agitation with air or gas. (This is by no means a complete list of uses . . .)

For More Information . . . send for your copy of our latest technical literature. It includes full details about today's most talked-about compressor . . . the F-M Rotary Compressor.

Tear Out This Advertisement . . . It's perforated for easy removal, office routing or filing. *Let's face it*—much equipment in the chemical, processing and mass-production industries is "here today, scrapped tomorrow"—obsolete long before it wears out. Be prepared for this eventuality. Start thinking about the Fairbanks, Morse Heavy-Duty Rotary Compressor . . . now!

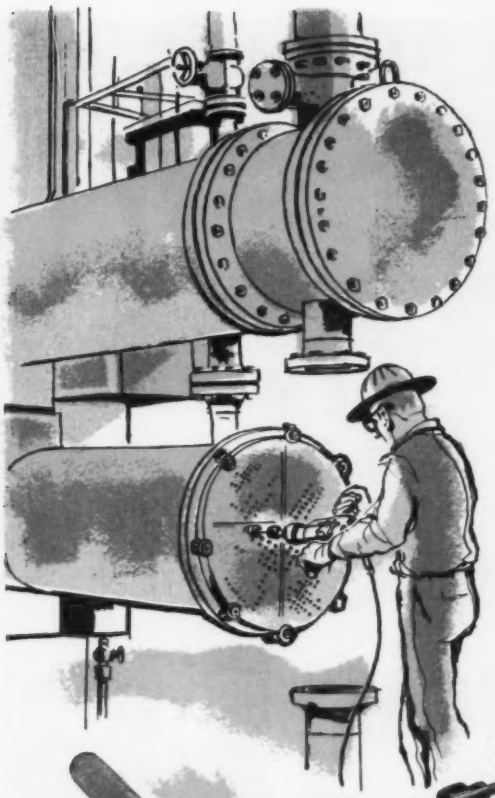
Fairbanks, Morse & Co.

600 South Michigan Avenue, Chicago 5, Illinois

A MAJOR INDUSTRIAL COMPONENT OF
FAIRBANKS WHITNEY CORPORATION, NEW YORK

ACOB 100.3

Printed in U. S. A.



For fast tube fabrication and maintenance

AMERICAN REFINERIES DEPEND ON AIRETOOL LEADERSHIP

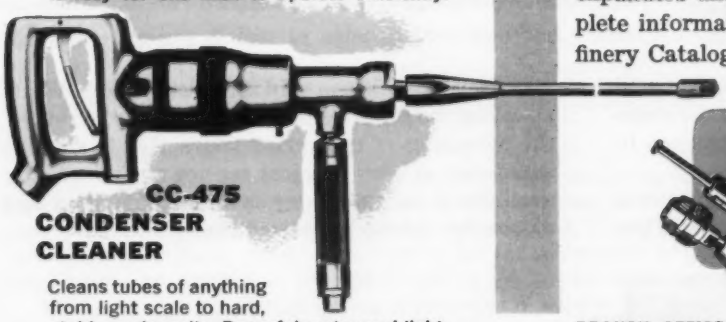
in pneumatic tool design

To keep tubular equipment in top shape and on stream, petroleum refineries rely on Airetool experience and pace-setting innovations in pneumatic tool development. Airetool performance-proven equipment is the result of more than 30 years of close association with the petroleum industry—in solving tube fabrication and maintenance problems. Thirty years of forging a lead in the design and development of air powered tools for the fast, efficient and economical maintaining of tubes of all types.

Airetool-designed tube maintenance equipment includes cleaner heads and brush head cleaners for straight and curved tubes with short radii, a complete line of cleaners and tube cutters, cutting tools, expanders and other tools and accessories. For complete information see our 28-page section in The Refinery Catalog or write:

AIRETROL

For air operated automatic control of tube expansion. Finger tip dial setting controls accuracy within .001 inch of desired setting. Airetrol rolls up to twelve ¼" to 1½" OD tubes a minute. Rugged air motor and compact unit with convenient roll throttle control makes it easy for one man to operate efficiently.



CC-475 CONDENSER CLEANER

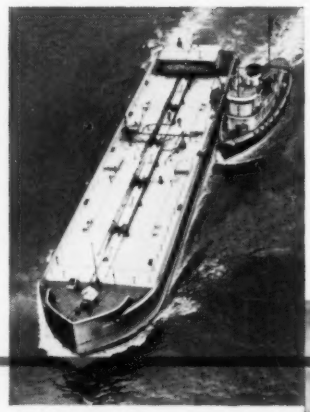
Cleans tubes of anything from light scale to hard, stubborn deposits. Powerful motor and lightweight tool make swift, easy, tube clean-out a one-man operation without rig. Built-in flushing system keeps drill head cool and washes out cuttings.

BRANCH OFFICES: New York, Chicago, Tulsa, Philadelphia, Houston, Baton Rouge
REPRESENTATIVES in principal cities of U.S.A., Canada, Mexico, South America, England, Europe, Puerto Rico, Italy, Japan, Hawaii
EUROPEAN PLANT: Vlaardingen, The Netherlands
CANADIAN PLANT: Brantford, Ontario

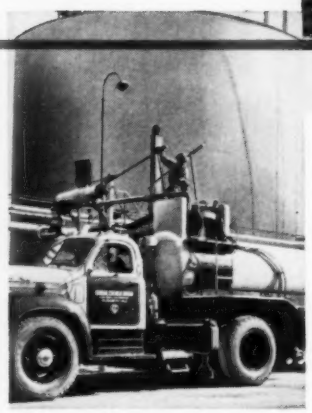
30 YEARS' EXPERIENCE IN PNEUMATIC TOOLS

For more data on advertised products, use Readers' Service Cards, last page.

To recover spent sulfuric, call on the leader in sulfuric



GENERAL CHEMICAL



Of General Chemical's 21 sulfuric plants, 15 are equipped to handle spent sulfuric! Here are their locations:

Anacortes, Washington
Barnet, British Columbia*
Baton Rouge, Louisiana
Buffalo, New York
Denver, Colorado
East St. Louis, Illinois
Elizabeth, New Jersey
El Segundo (Los Angeles), California
Hegewisch (Chicago), Illinois
Newell, Pennsylvania
North Claymont, Delaware
Port Chicago (San Francisco), California
Richmond (San Francisco), California
River Rouge, Michigan
Valleyfield, Quebec*

*In Canada: Allied Chemical Canada, Ltd.

If you are seeking to recover spent sulfuric acid from your operations and your plant is in the vicinity of any of those listed above, it may pay you to talk to General Chemical.

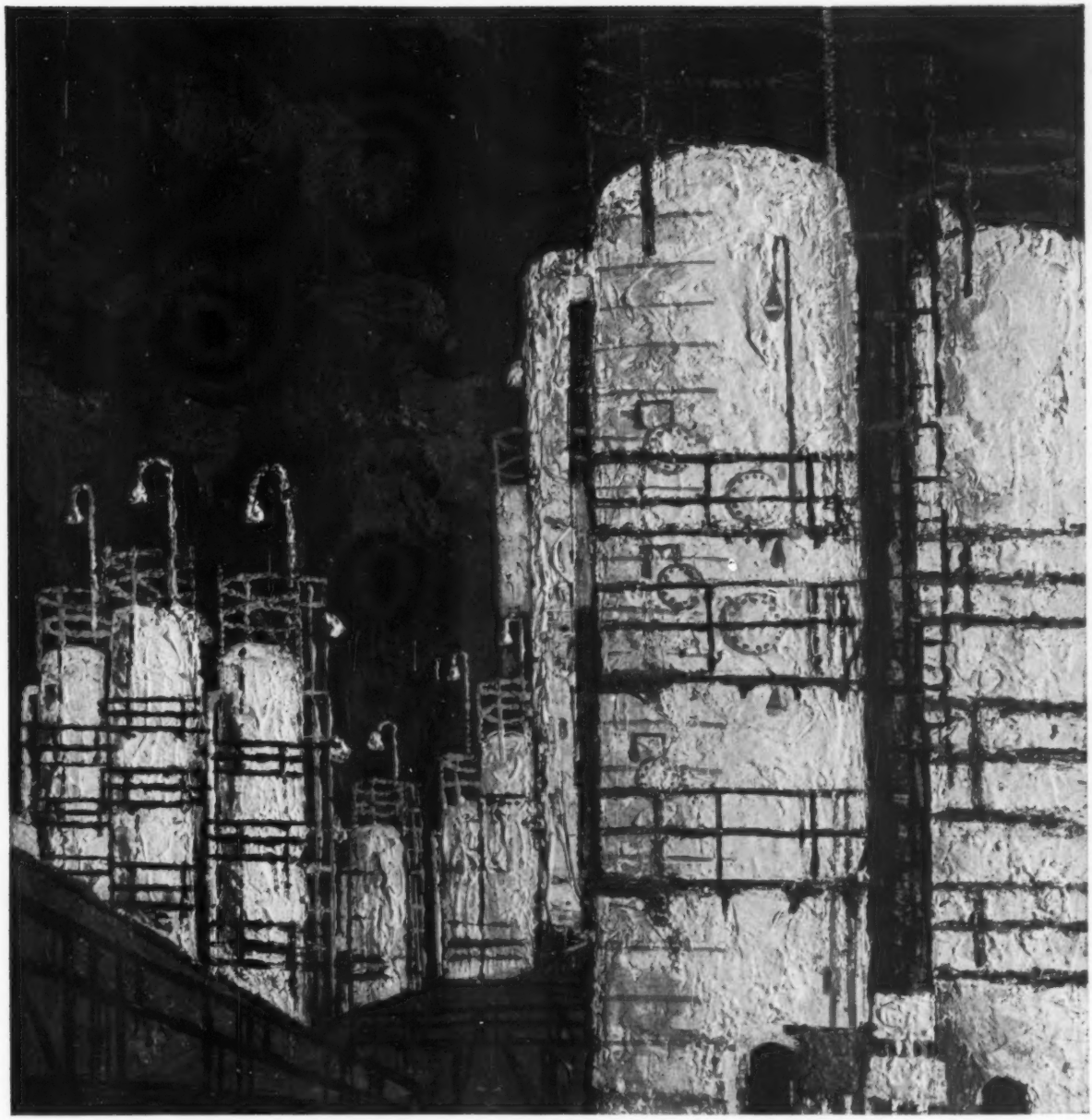
As the nation's leading sulfuric producer, General has years of experience in recovering many types and strengths of spent acid for its customers. While all cannot be reclaimed, we will be happy to review the economics of recovering yours. As always, the assistance of our technical service staff is readily available to help solve any spent acid handling and disposal problems you may have.

Basic to America's Progress

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N.Y.

For more data on advertised products, use Readers' Service Cards, last page.



More drying per dollar in nine towers showed Columbia Gulf Transmission why it pays to

mix imagination with Alcoa Aluminas

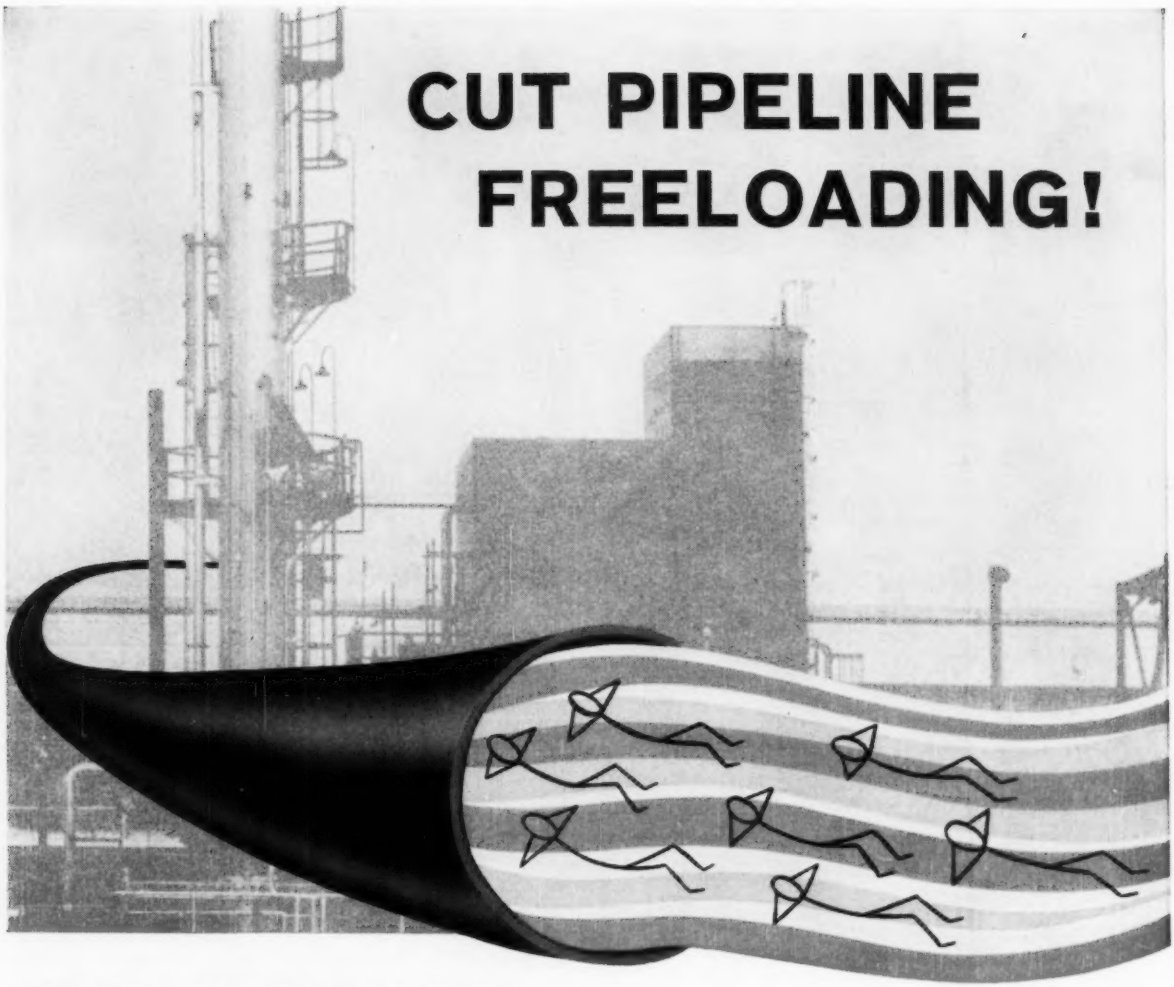
Nearly ½-million lbs of Alcoa® Activated Alumina is giving Columbia Gulf Transmission Co. maximum drying capacity per dollar in one of the world's largest natural gas drying operations. Used in nine towers at the company's Rayne, Louisiana, compressor station, the activated alumina dries 690 MMSCF of natural gas per day. Average water content of gas entering the towers is 5-6 lbs water/MMSCF. Water content of the effluent gas is below ½ lb water/MMSCF. Each tower is on stream for 24 hours with a reactivation time of 6 hours. Columbia Gulf Transmission has found that no other desiccant can furnish such efficient drying at such low cost.

When effective, economical drying is your aim, it pays to mix imagination with Alcoa Activated Aluminas—the oldest commercial desiccant available and still the most efficient. For detailed data, send for a free copy of the Alcoa White Data Sheets and a comprehensive Gas and Liquid Dehydration Questionnaire. Aluminum Company of America, Chemicals Division, 708-F Alcoa Building, Pittsburgh 19, Pa.

ALCOA CHEMICALS
ALUMINUM COMPANY OF AMERICA

For finer products . . . let Alcoa add new dimension to your creative thinking!

For more data on advertised products, use Readers' Service Cards, last page.



AIR LIQUIDE eliminates "dead head" gas by low-temperature separation

Here's the way to rid pipelines of unwanted nitrogen, upgrade natural gas and make profits on superfluous yet valuable gases. *Install an American Air Liquide low-temperature gas separation plant*, economical to operate and requiring minimum of attention.

Many natural gas pipelines are carrying "dead head" nitrogen that builds up compression, increases transmission costs and reduces pipeline payload. This nitrogen is removed — at pipeline pressure — by the American Air Liquide process.

At the same time that your natural gas is upgraded, unwanted gases are removed — yielding further profit instead of going to waste as inerts, flue gases or engine exhausts along with a loss of valuable heat. To quote only one example, the extraction of helium offers considerable direct profit from this efficient, economical process.

For further information on our complete low-temperature service — from process engineering of complete plants and custom-designed equipment to technical consultation and plant erection — write or call us: Chrysler Building, 405 Lexington Ave., New York 17, N.Y.

PROFITABLE ADVANTAGES OF NITROGEN REMOVAL

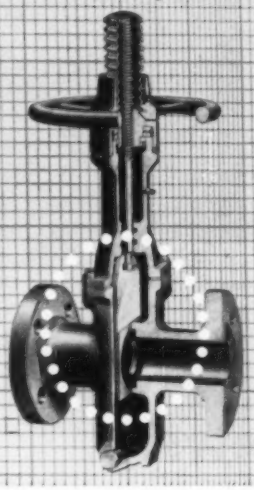
1. Raises calorific value — more BTU's per pipeline.
2. Simultaneously removes heavier hydrocarbons for separate sale.
3. Enables compressors and pipelines to handle capacity payloads.
4. Improves flow characteristics: reduces density and viscosity; reduces pressure drops.
5. Cuts compressor fuel costs.
6. Produces helium simultaneously from helium-bearing gases.

IN CANADA:
L'Air Liquide,
1210 Sherbrooke St. W.,
Montreal, Que.

AMERICAN AIR LIQUIDE
ENGINEERING & CONSTRUCTION DIVISION
OLDEST IN EXPERIENCE · NEWEST IN DESIGN
405 LEXINGTON AVE., NEW YORK 17, N.Y.

"Smooth sealing... upstream and down"

PRODUCT OF W-K-M's
Creative Engineering



FLOATING SEATS MAKE THE SEAL

Seats are specially formulated rubber molded to a hardened steel insert. They float against the gate. When the gate closes, line pressure forces the gate against the downstream seat making a tight seal. The upstream seat maintains its seal against the gate for an upstream seal. The valve provides a tight seal under little or even no line pressure or under vacuum conditions.

5925

W-K-M's new Pressure Sealing Gate Valve

Almost without effort . . . you get a tight seal on *both* sides of the line. The secret? A unique seat design that puts line pressure to work *for* you. The greater the pressure, the tighter the seal!

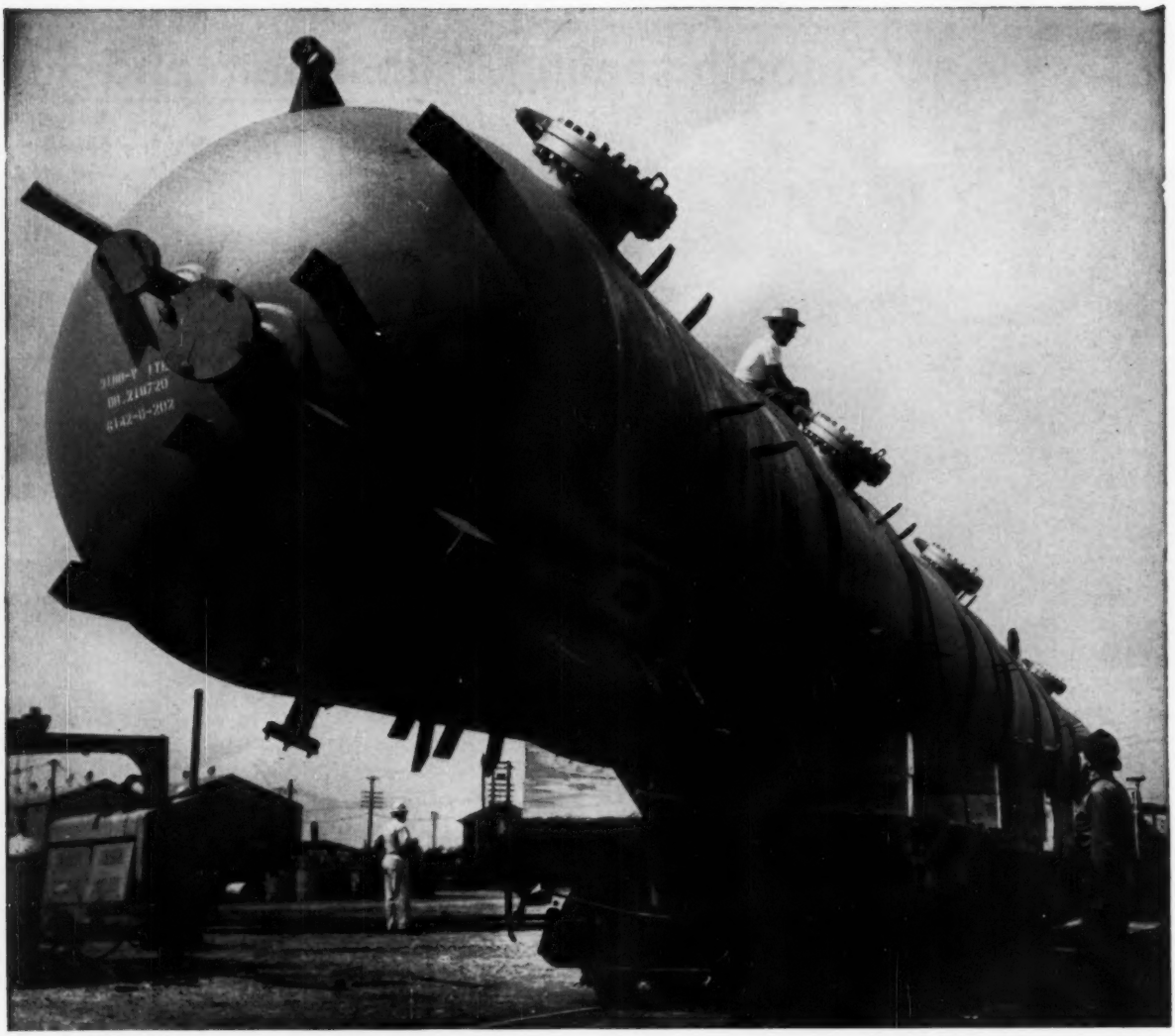
Seats automatically adjust for wear . . . automatically relieve excessive body pressure. And on-the-line overhaul is easy.

Specify W-K-M's economical new Pressure Sealing Gate Valve for pressures to 720 psi (cwp) and temperatures to 250° F. Sizes 2″ through 30″. *At leading supply stores everywhere.*

WRITE FOR CATALOG 1200

W-K-M

DIVISION OF acf INDUSTRIES
INCORPORATED
P. O. BOX 2117, HOUSTON, TEXAS



THIS ENTIRE VESSEL was radiographed. Built for use by Socony Mobil Oil Company, Incorporated, it was stress relieved in thirds, and the two joints were stress relieved locally. The unit contains 30 uniflex trays of 96" diameter. Overall weight: 152,000 lbs.

Among the largest in use

...built by Newport News

This Debutanizer with a 110 feet 6 inches over-all length is typical of units that are readily built by Newport News . . .

In fact, Newport News can fabricate almost any type of pressure vessel or other heavy equipment used in the petroleum, chemical or other processing industries.

But at Newport News you'll find more than large productive capacity.

In vast fabricating shops, in huge machine shops, foundries and forging plants, Newport News craftsmen complete your order with specialized techniques. Plant methods . . . developed as a result of specializing for more than half a century . . . enable Newport News to provide money-saving answers to all sorts of heavy equipment problems.

Newport News craftsmen handle the job exactly as you want it done . . . for maximum results per dollar invested. So let us bid on your present or future projects. Learn how Newport News can help you. Send for our illustrated booklet entitled, "Facilities and Products"...it's yours for the asking.

Engineers — Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

COMPARE

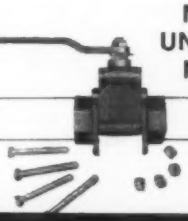
THE ECON-O-MISER BALL VALVE...

The most advanced replacement valve for ON-OFF applications

Engineered design simplicity provides superior performance plus real dollar savings. • Remove 4 bolts—the center section lifts out—unions are eliminated. Service time and cost are reduced to a matter of minutes and pennies, and the valve is right back in operation. Costly spare parts are a thing of the past. • The Econ-O-Miser Ball Valve answers thousands of difficult application problems—simply—efficiently. Available from ¼″ through 6″ size range, it is ideally suited to difficult media, because of its smooth round flow and quarter-turn operation. • If you're interested in valves, you're interested in the Econ-O-Miser Ball Valve. Complete, up-to-date technical information is yours for the asking.

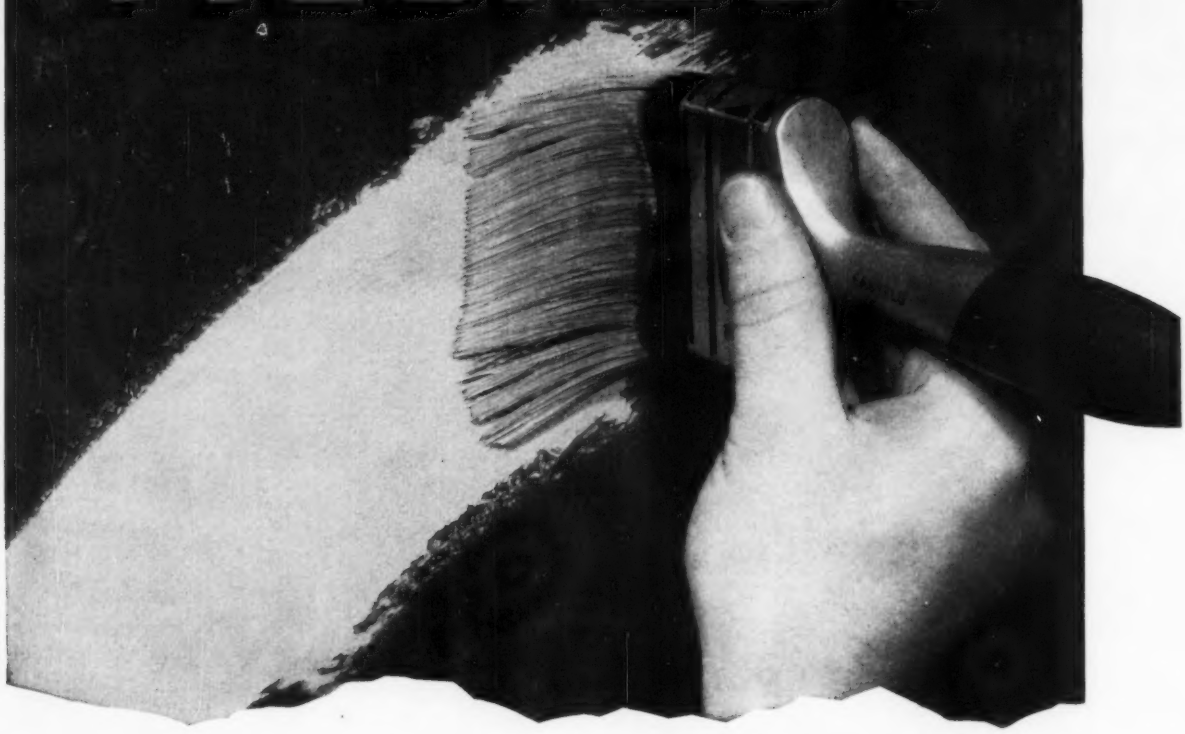
WORCESTER VALVE CO., INC.

16 PARKER STREET, WORCESTER, MASS.



NO UNION NECESSARY!

TYGORUST—



locks vinyl top coats to damp or dry rusted steel

This FREE Painting Manual can help make your fight against corrosion easier

Contains a wealth of practical data in its many sections: how to simplify surface preparation; what top coating to use for over one hundred corrosive conditions; how many coats; how to maintain coatings in good condition; common spraying troubles and how to remedy them. It's free on request. Ask for the Tygon Painting Manual.

- ***Holds surface preparation to a minimum***
- ***Can be top coated within an hour***

Tygorust Primer licks the big problem in using vinyl-based protective coatings: **Adhesion.** Not only does Tygorust assure a well bonded top coat to the steel it is to protect, but it does it economically.

Forget sandblasting. Tygorust actually works better on rusted surfaces. Just wire brush loose or flaky rust and apply Tygorust. The steel can be dry or damp—it makes no difference. (You can brush or spray Tygorust on dry steel—damp steel should be brushed.) Use Tygorust on concrete, too.

You can overcoat Tygorust with any finish material; but for real corrosion-resistance, make the finish coats Tygon—the corrosion-resistant paint that has stood the test of time.

Plastics and Synthetics Division

U. S. STONEWARE

AKRON 9, OHIO

342E-1

New heat-resistant alloy

SUPERTHERM

(Trade-mark)

for castings operating in the 1800-2300°F range

DEVELOPED AT OUR RESEARCH LABORATORIES

in Mahwah, N. J., Supertherm is field tested and proved. It is a superior alloy in this temperature range for static, centrifugal and shell-molded castings.

Mail the coupon, below, for technical information on composition*, physical and high-temperature properties.

*Patent Pending

Electro-Alloys Division
2026 Taylor Street
Elyria, Ohio

Please send me technical information on SUPERTHERM

Name_____

Company_____

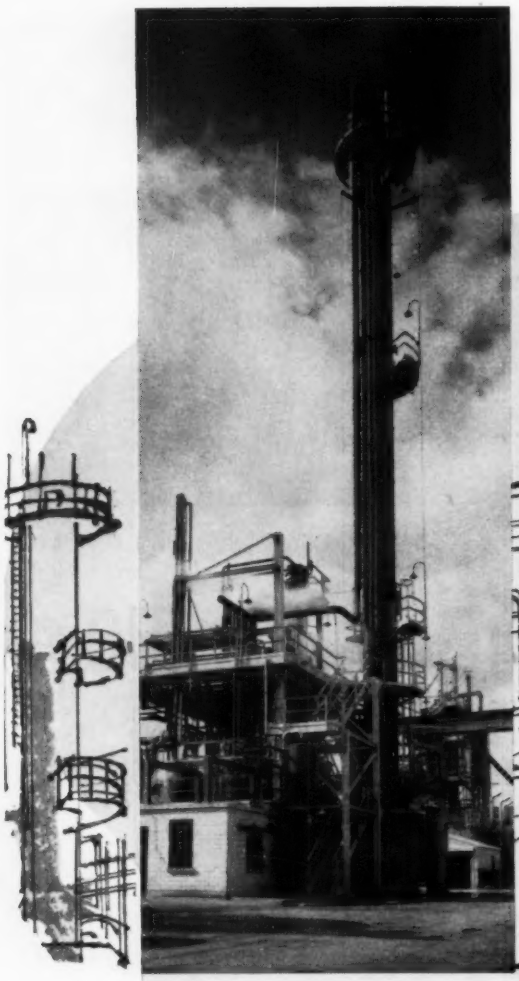
Address_____

City_____ Zone___ State_____

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

For more data on advertised products, use Readers' Service Cards, last page.



*'62 could be the year for you

*A SUBSTANTIAL INCREASE IN PROCESS CAPACITY will be needed by 1962, according to reliable estimates...NOW is the time to start your planning!

PROCON®

PROCON INTERNATIONAL S. A., CHICAGO, ILL., U. S. A.

PROCON (CANADA) LIMITED, TORONTO, ONTARIO, CANADA

PROCON (GREAT BRITAIN) LIMITED, LONDON, W. C. 2, ENGLAND

PROCON PTY. LIMITED, SYDNEY, AUSTRALIA

PROCOFRANCE S.A.R.L., PARIS, FRANCE

PROCON LIMITADA, SAO PAULO, BRAZIL

VICAPROCON, S. A., CARACAS, VENEZUELA

REACTORS AND TOWERS THAT PRODUCE PROFITS . . .

One thing petroleum, petrochemical and chemical plants have in common: Each consists of reactors, piping, tanks, towers, heaters, pumps and other components that must work together to produce profitable products.

Your new processing facilities do just that when you entrust the job to Procon. A world-wide organization specializing in process construction, Procon builds, within your budget, plants that not only meet full performance specifications, but often exceed them!

Before you get too far in planning your next move, call in Procon. We'll be glad to discuss your needs with a view to preparing a detailed proposal.

PROCON *Incorporated*

1111 MT. PROSPECT ROAD, DES PLAINES, ILLINOIS, U. S. A.

WORLD-WIDE CONSTRUCTION FOR THE PETROLEUM, PETROCHEMICAL, AND CHEMICAL INDUSTRIES

This bubble-tight seal

can't cause contamination... costs nothing to maintain!

Stockham's NON-LUBRICATED Wedgeplug*'O-SEAL' Valve

Meet the valve that gives you permanent, absolute shut-off without sealing compounds or lubricants. The valve that eliminates the danger of contamination resulting from excess lubricant being forced into the product stream. Eliminates the danger of product mixing in manifolds.

The valve is Stockham's NON-LUBRICATED Wedgeplug "O-Seal" — now widely used in general purpose services. Two Teflon† "O" rings in the plug provide the pressure-seal — provide permanent "bubble-tight" shut-off in all cases.

The "O-Seal" is guaranteed not to stick . . . provides double-block and bleed in most services . . . has flawlessly machined metal seats to provide shut-off in case of fire.

*Patented — †Teflon, Dupont Trademark

Call your Stockham Distributor or Sales Representative now, or write Stockham for complete details about the "O-Seal."

Complete ranges of sizes and types available.

CAST IRON-MALLEABLE AND DUCTILE IRON PIPE FITTINGS — BRONZE, CAST IRON, DUCTILE IRON, CAST AND FORGED STEEL VALVES.

SOLD ONLY THROUGH DISTRIBUTORS

WEDGEPLUG VALVE COMPANY

Division of

STOCKHAM VALVES *and* FITTINGS

General Offices and Plant

4003 North 10th Avenue • Birmingham 2, Alabama

POWELL
giant in-stock valve supply for quick delivery

Powell maintains one of the largest in-stock supplies of bronze, iron, steel and corrosion resistant alloy valves in the world. So you can receive immediate valve delivery from Powell's factories or your nearby distributor's stocks and avoid costly operational delays or plant shutdowns.

For quick action, just pick up your phone and contact your local Powell Valve distributor or The Wm. Powell Company direct. With our 114 years of valve manufacturing experience, we can fill your valve needs and solve your valve problems! Let us hear from YOU—TODAY!

THE WM. POWELL COMPANY DEPENDABLE VALVES SINCE 1846 CINCINNATI 22, OHIO **world's largest family of valves**

3 REASONS WHY

EVERY REFINER SHOULD USE...

There are three important and different reasons—and ways—for refiners to use copper deactivator. One or the other applies to every refinery.

COPPER-FREE GASOLINES easily pick up copper in treating, from condensers, valves, lines or contaminated blending stock —or even during transfer of gasoline in bulk or service stations.

NORMAL GASOLINES usually show traces of copper, often enough to reduce or nullify the effect of antioxidants. Through the use of a small amount of AW(50) the amount of inhibitor may sometimes be reduced, at an overall reduction in additive cost!

DISTILLATE OIL BLENDS often form insoluble sediment and darken in color. Whether inhibitors are used or not, a small quantity of AW(50) added to fuel oils minimizes color and sediment deterioration.

UOP Copper Deactivator AW(50) remains liquid down to 0°F, is convenient to use, and is approved for military fuels including aviation gasoline. Write for samples.

UOP
COPPER
Deactivator
AW® 50

*

See our PSE*

Correct selection and most effective use of petroleum inhibitors and additives involves expert analysis and consideration of many factors relating to your feedstock and methods of processing. As specialists for over a quarter-century, UOP is able to provide unparalleled field service, brought to you by a member of our staff of Product Sales Engineers. For detailed information on the UOP family of superior inhibitors and additives, call or write our Products Department.

UOP®

WHERE RESEARCH TODAY MEANS PROGRESS TOMORROW

UNIVERSAL OIL PRODUCTS COMPANY

30 Algonquin Road. Des Plaines, Illinois, U.S.A.

For more data on advertised products, use Readers' Service Cards, last page.

*Completely adjustable**

Flooded Disc Scrubber

Removes Sub-Micron Fumes

The Research-Cottrell high efficiency scrubber uses the unique flooded disc principle for removing sub-micron fumes in steel-making furnaces and chemical processing.

As shown in the illustration, the outstanding feature of this scrubber is the simple, adjustable "flooded disc." The flooded disc adjusts for maximum cleaning efficiency over a wide range of operating conditions.

* *Automatic positioner immediately adjusts the disc to meet your varying gas and dust control problems.*

Research-Cottrell, with over 48 years of industrial gas cleaning experience, will be glad to consult with you on any specific problem.

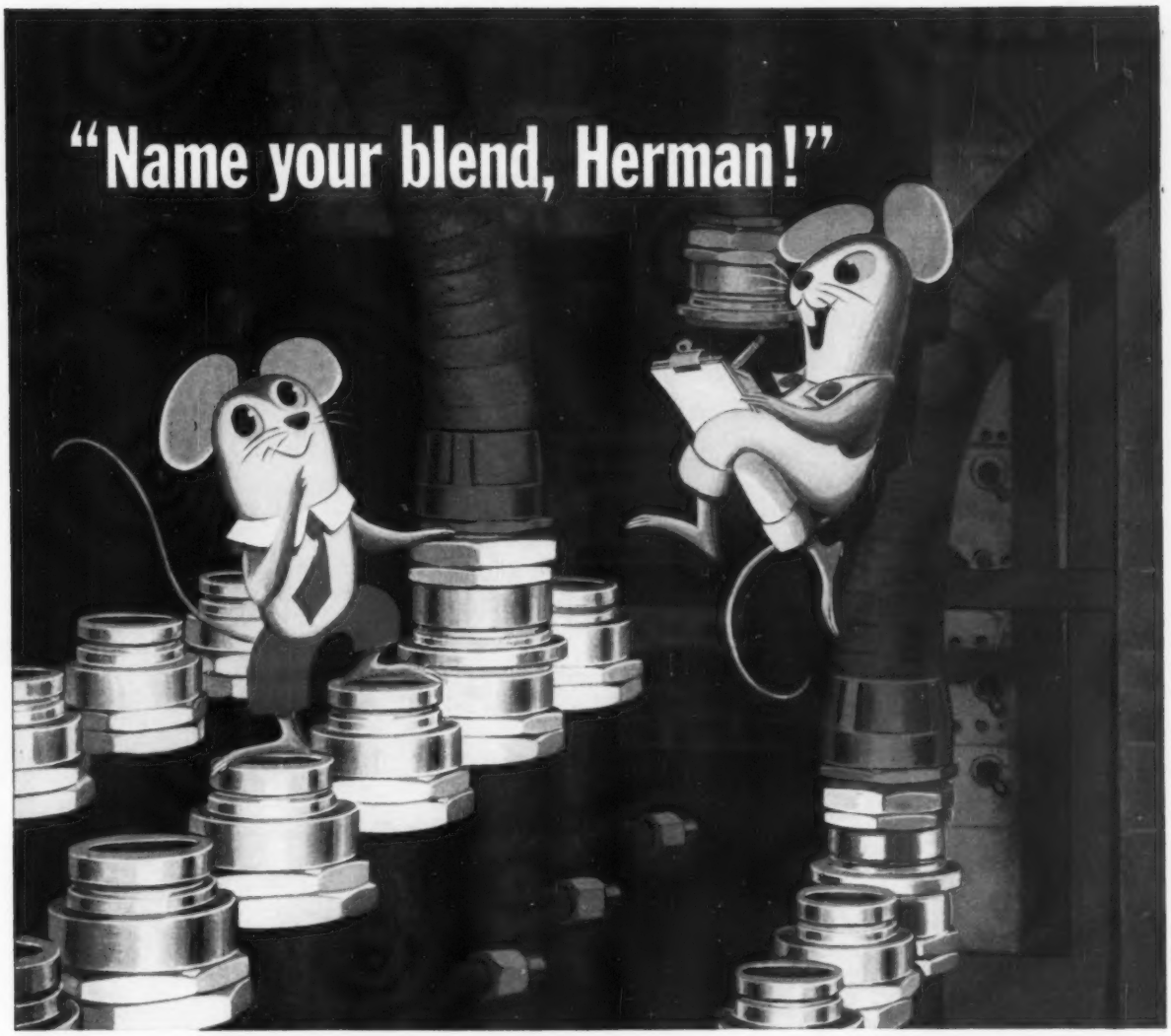
For further information, write for Bulletin 110.

Research-Cottrell

RESEARCH-COTTRELL, INC., Main Office and Plant: Bound Brook, N. J.
Representatives in principal cities of U.S. and Canada

RESEARCH COTTRELL INC. TRADE MARK

RC207



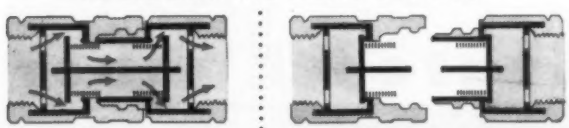
Here's the new, easy way to blend fluids: with Snap-Tite valved couplings on flexible lines

Now there's no need to laboriously open and close a lot of shut-off valves when you're blending petroleum products or other chemical fluids. With Snap-Tite valved couplings on flexible lines you can quickly switch hoses to any base stock line as required. Mixing is faster: you can perform more operations at one time . . . with no danger of contamination of base stocks by interflow through leaky valves! Valves with Snap-Tite couplings instantly shut off the flow when disconnected, and prevent run-out from overhead lines.

Under this arrangement, you store only base stocks to achieve infinite variations in blending. Not only do you save space, time and labor, but by eliminating shut-off valves and associated headers and permanent piping, you save substantially on equipment. In a recent installation (Standard Oil at Richmond, Cal.) the coupling cost was approximately one-third that of permanent piping!

For information, write for Snap-Tite Catalog No. 59. Ask for the name of your local Snap-Tite representative. There is no obligation.

TO USE SNAP-TITE VALVED COUPLING:



CONNECT—Full flow instantly

DISCONNECT—Stop flow instantly

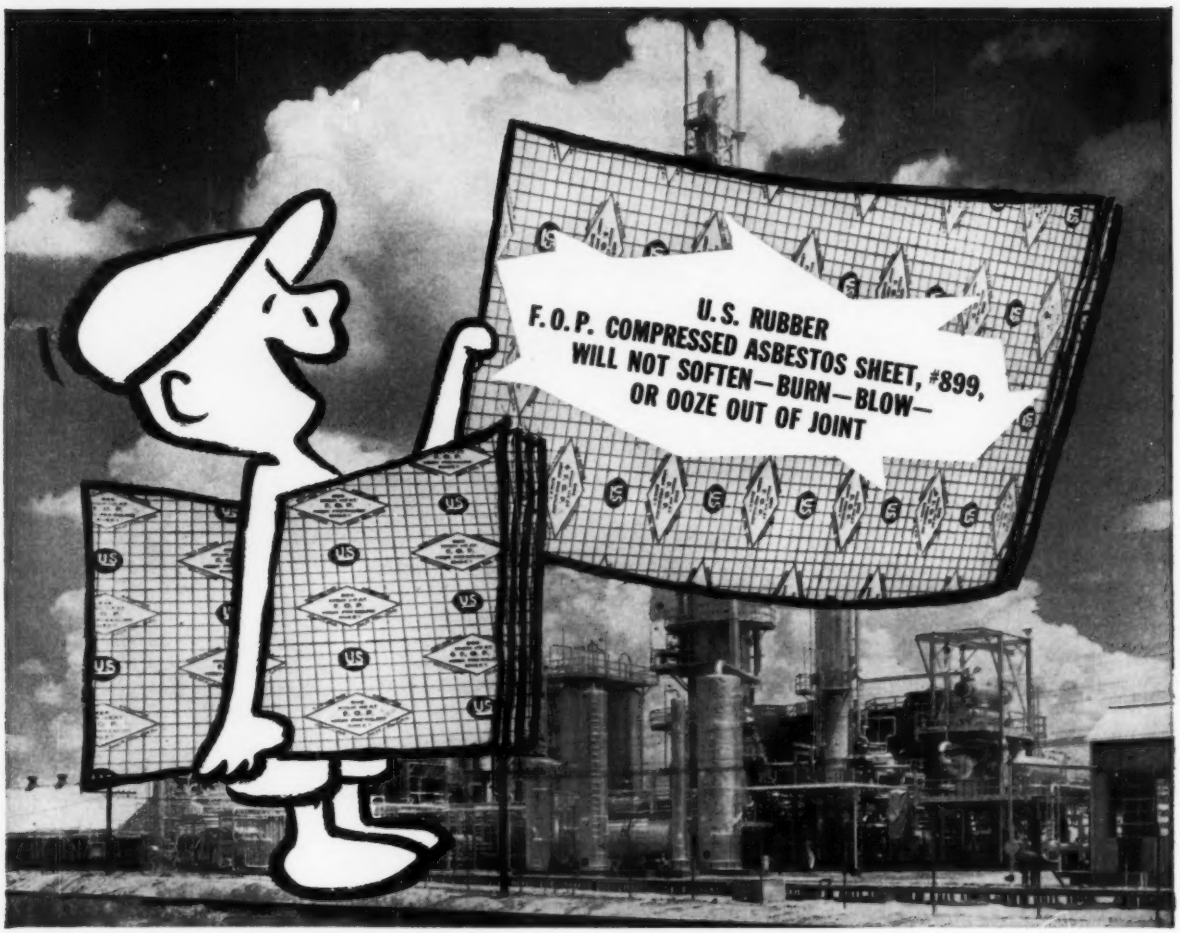
Snap-tite

ST-59-05

UNION CITY, PA.

US RUBBER PACKING

HOT NEWS for Hot Joints and Flanges



This is the packing that's making headlines where the going's the hottest . . . where flanges or joints must be packed against superheated or saturated steam, air, water, ammonia, gases, oil, gasoline and many chemicals.

U. S. Compressed Asbestos Sheet Packing was the first of its type developed particularly for refineries and chemical plants. It is made by a special process from selected long-fibre asbestos and bonded with exacting combinations of heat-resistant materials. Balanced construction makes this packing ideal for use as Still Head Gaskets.

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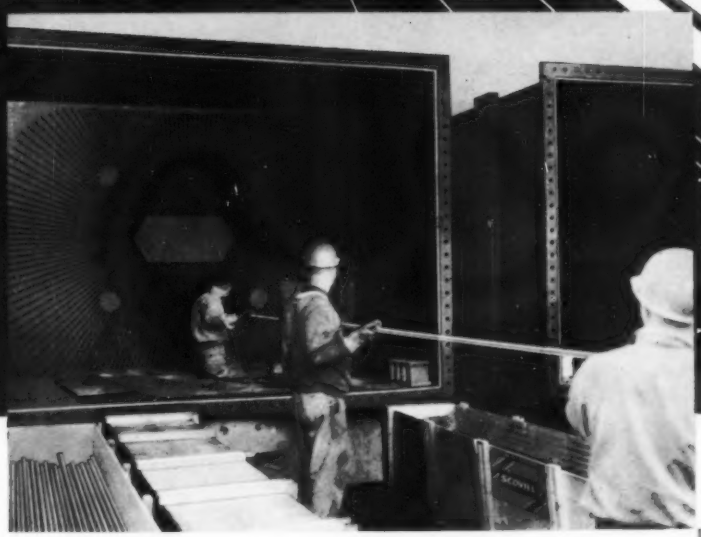

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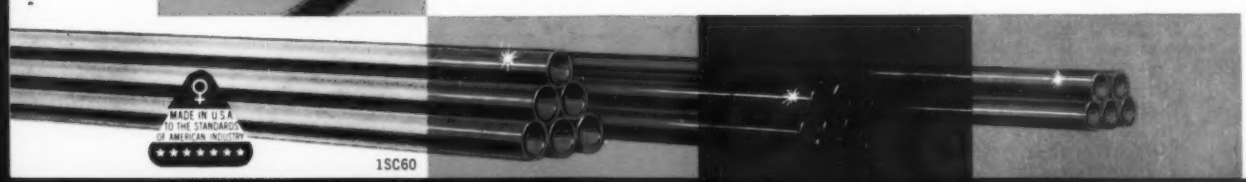

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— M. J. Rathbone, President

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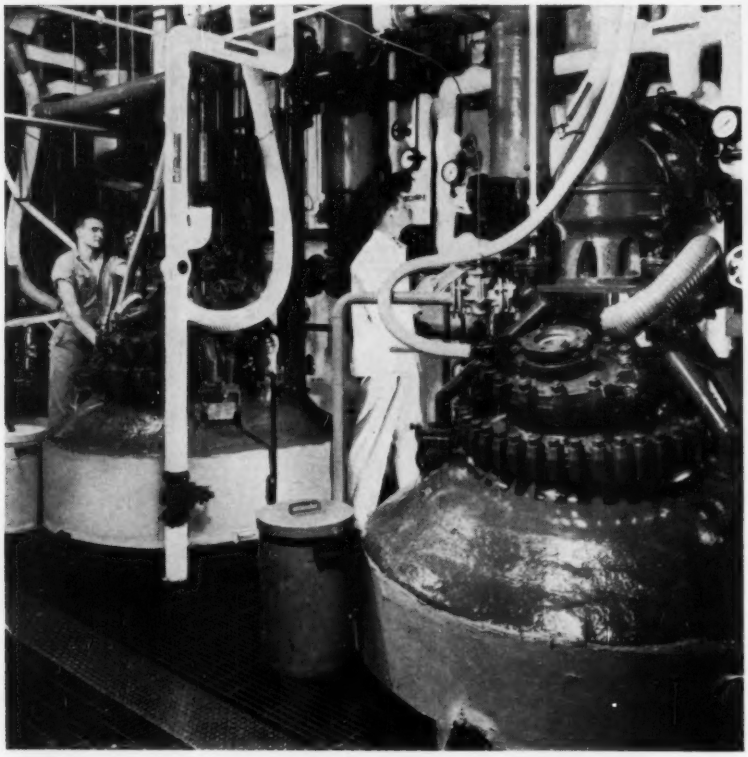

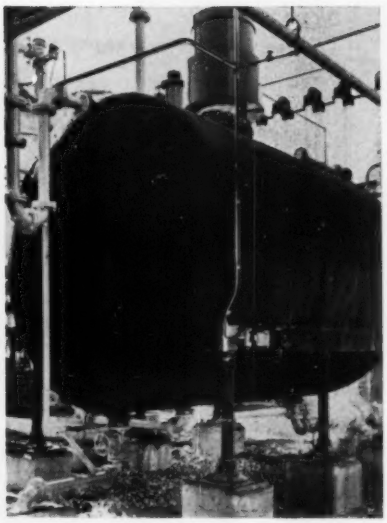

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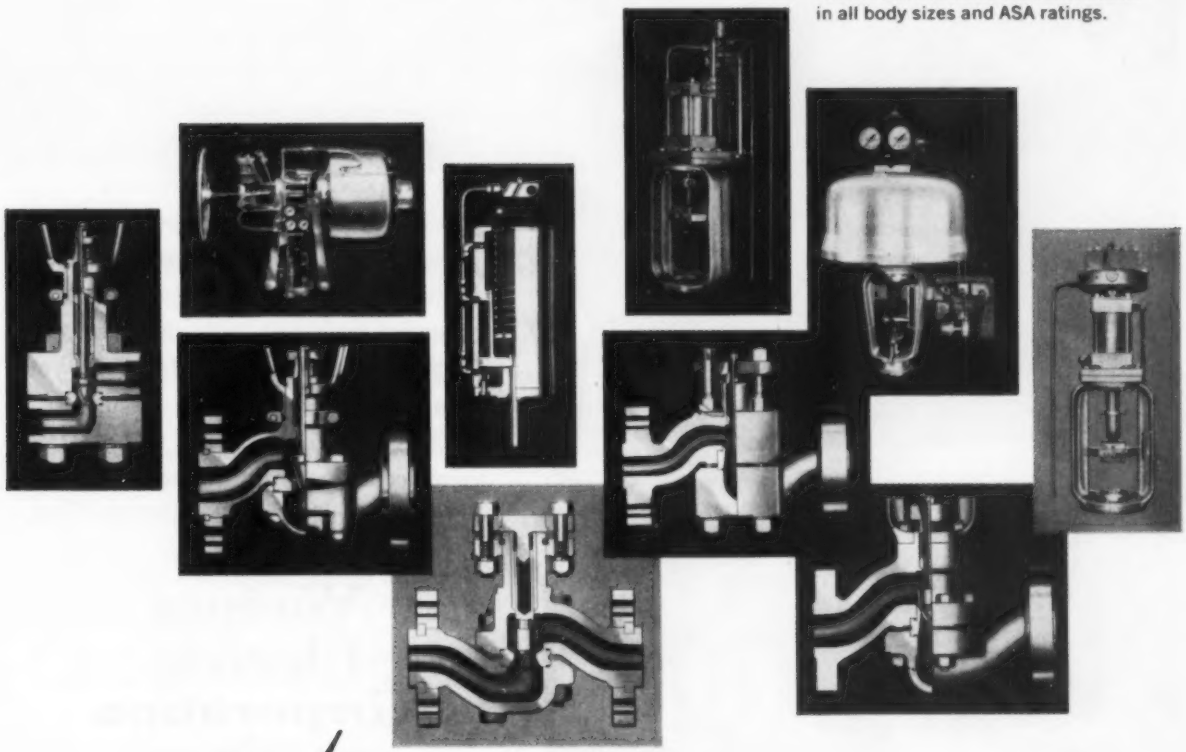

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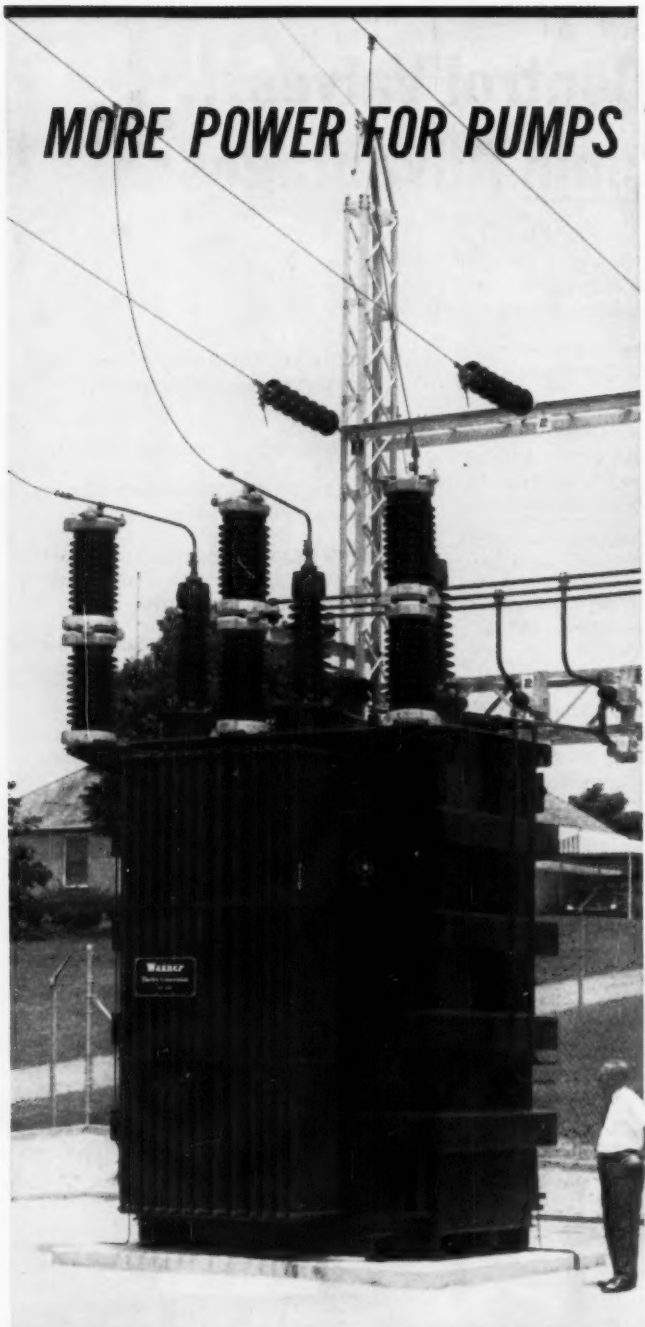

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The Neese operation was originally served with power from a 44 kv system substation. However, the size of the pumping load—which includes some 1800 hp motors—became too great for the substation to handle adequately.

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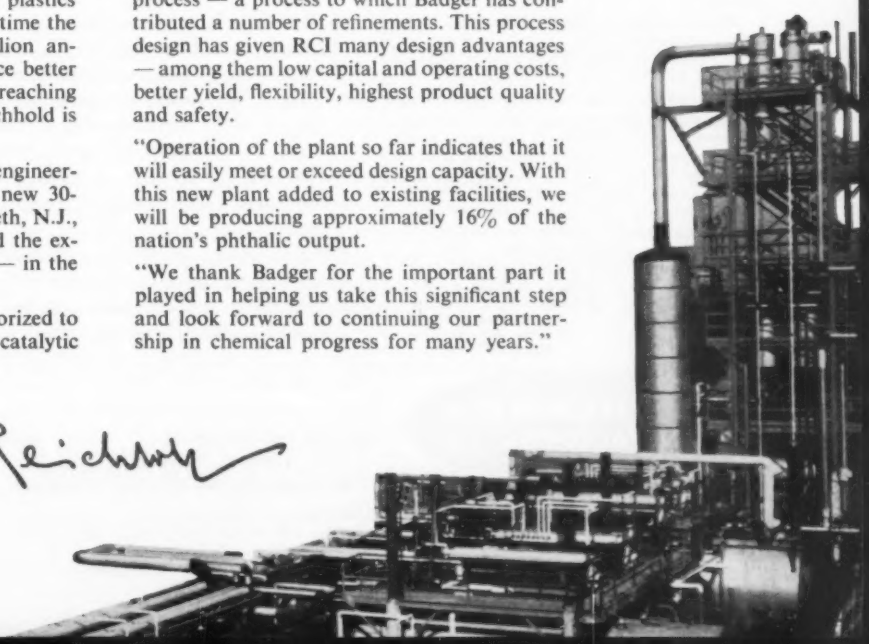
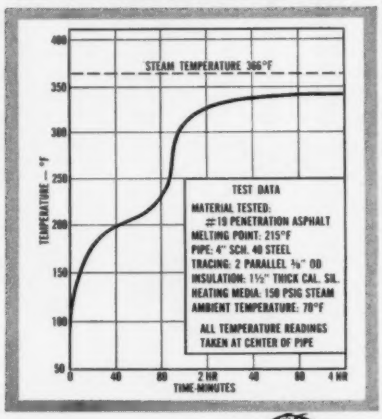
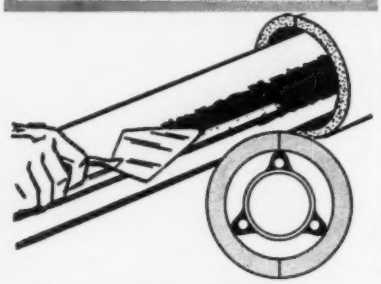
"We thank Badger for the important part it played in helping us take this significant step and look forward to continuing our partnership in chemical progress for many years."

Henry W. Reichhold



Eliminate Asphalt heating problems with THERMON HEAT TRANSFER CEMENT





On seventy miles of asphalt line, some fifty refineries have used Thermon Heat Transfer Cement to eliminate the physical problems and expense of internal tracing and steam jacketing. A non-metallic, adhesive compound with highly efficient heat transfer characteristics, Thermon Heat Transfer Cement used on asphalt lines and equipment

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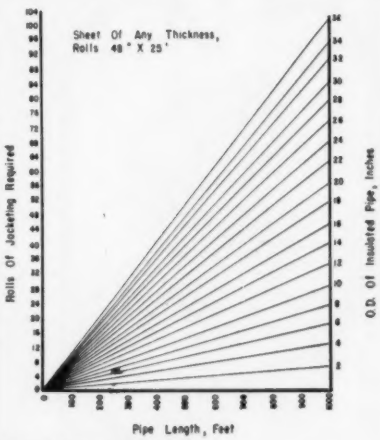

Revises Chart

To the Editor:

We noted with interest the article, "Charts Calculate Sheathing Quickly," contained on Page 172 of the February, 1960 PETROLEUM REFINER. We believe however, that based on statements in the text, the charts are incorrect.

1. Assuming that each roll contains 100 sq. ft. of material, the number of rolls required should be independent of the material thickness.
2. The external surface area of a 36-inch diameter insulated pipe, 1,000 feet long, is approximately 10,200 sq. ft. (including 2-inch longitudinal laps and 3-inch circumferential laps). At 100 sq. ft. of material per roll, this indicates a requirement for 102 rolls.
3. While anodized insulation jacketing would be attractive, it would be prohibitively expensive. Also, the organic dyes would tend to fade in direct sunlight. We would recommend using coiled sheet with a mill-applied thermo-setting acrylic resin coating. This finish is considerably less expensive, stands up well to weathering, and forms readily without crazing.

We are greatly pleased to learn of increased acceptance of aluminum by industry. We do not feel however, that we should assist where indicated in assuring the accuracy of published data on aluminum. We are attaching a proposed revision to Mr. Ziemke's chart.

James H. Lovell, Jr.
Industry Sales, Kaiser Aluminum
Oakland, Calif.

AUTHOR'S COMMENT

Paul C. Ziemke, who contributed the February article, welcomed this authoritative information. "Some fading has occurred as expected," he commented. "Mr. Lovell's graph is an improvement over ours."

How Professional?

"How Professional Is Your Management?" by Dr. John J. McKetta which appeared commencing on Page 190 of the February 1960 issue of PETROLEUM REFINER, continues to draw mail. Some of the comment is of such nature that writers preferred that their names not be used.

"Most of the letters received were from individuals who rated their management high—above 70 percent," Dr. McKetta said. "I received only one letter from an individual who rated his company below 50 percent although many individuals told me in person that they had done so."

One letter received ran as follows:

"I'd like to paraphrase you: 'What could happen?' It seems to many technical men that schools have but one goal in mind—to turn out students. Indeed this is quite admirable, but many times this goal is sought so ruthlessly that the faculty seems to have neither the time nor inclinations to worry with problems which are not obstructions to that goal."

COMMENT

Comment by the author, who is chairman of the Chemical Engineering Department at the University of Texas, on that one was a single word: "Ouch!"

Two Points Checked

To the Editor:

I enjoyed the special report in your April, 1960 issue regarding "Operator's Handbook for Gasoline Plants, Part 8—Orifice Meters." It is filled with good information and well presented. These two points, however, I respectfully call to your attention for rechecking:

1. Example Calculations for Gas Flow —Re: *Absolute Pressure.*

   Barometric (or Atmospheric) pressure, *rather than pressure base,* should be added to psig to obtain the absolute flowing pressure. Pressure base is not a square root func-

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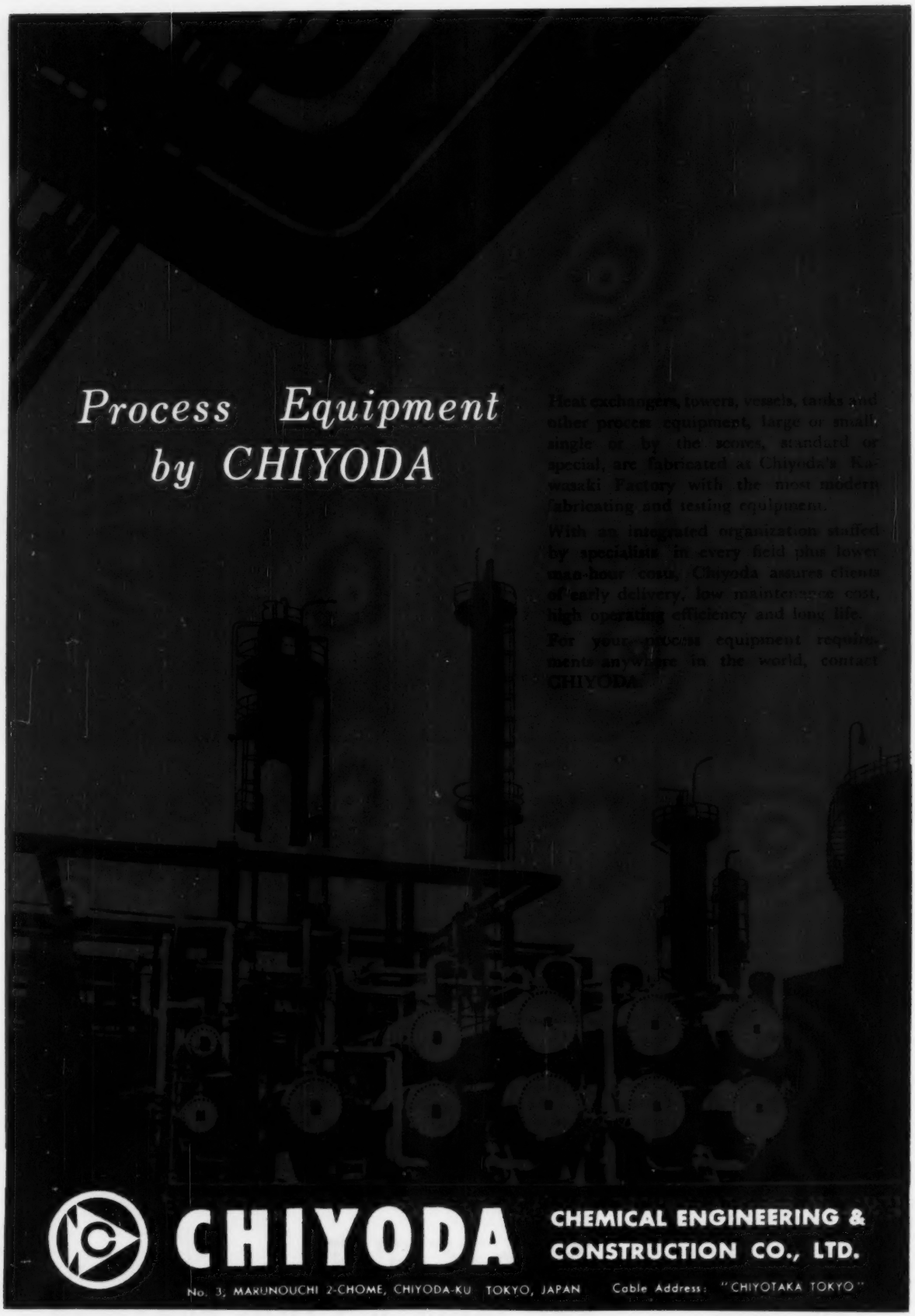
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tion and should not be confused with a condition of flow. Note that the absolute pressure as shown does not carry the square root sign, which is probably a printing error.

2. Example Calculations for Liquid Flow—Re: *Use of square root chart.*

In using the square root chart on a 50-inch meter the reading would be 7.75 sq. rt. units, *instead of 5.5 sq. rt. units,* for 30-inch differential water pressure. The meter factor for a 50-inch meter when using the square root chart is 0.7071. Therefore, the combined factor would be 135 *instead of 191.*

I know that much diligent work is involved in the article on orifice meters, and I hesitate to question such an excellent presentation.

U. E. Thorne
Goliad Oil & Gas Company
Calgary, Alberta

AUTHOR'S COMMENT

Reader Thorne is right on both counts. Static gage pressure is converted to absolute pressure by adding barometric pressure, not pressure base. However, in this example, the two values (barometric and base) are the same (14.65 psia) fortuitously. Also, it was a typographical error that the absolute pressure did not carry a square root sign.

On the liquid flow example, a correction could be made as suggested. Actually, the example was based on the 100-inch mercury type (not 50-inch as noted), so that for this case the combined factor would still be 191.

We're on Top

To The Editor:

Articles like "What You Need to Design Thermosiphon Reboilers" appearing in the February issue along with complete coverage of industry news, is what makes PETROLEUM REFINER the TOP magazine for petroleum and petrochemical people.

R. B. Galbreath
Lake Charles, La.

The Editors of PETROLEUM REFINER invite reader comment on topics of timely interest to the oil, gas, and petrochemical processing industry.

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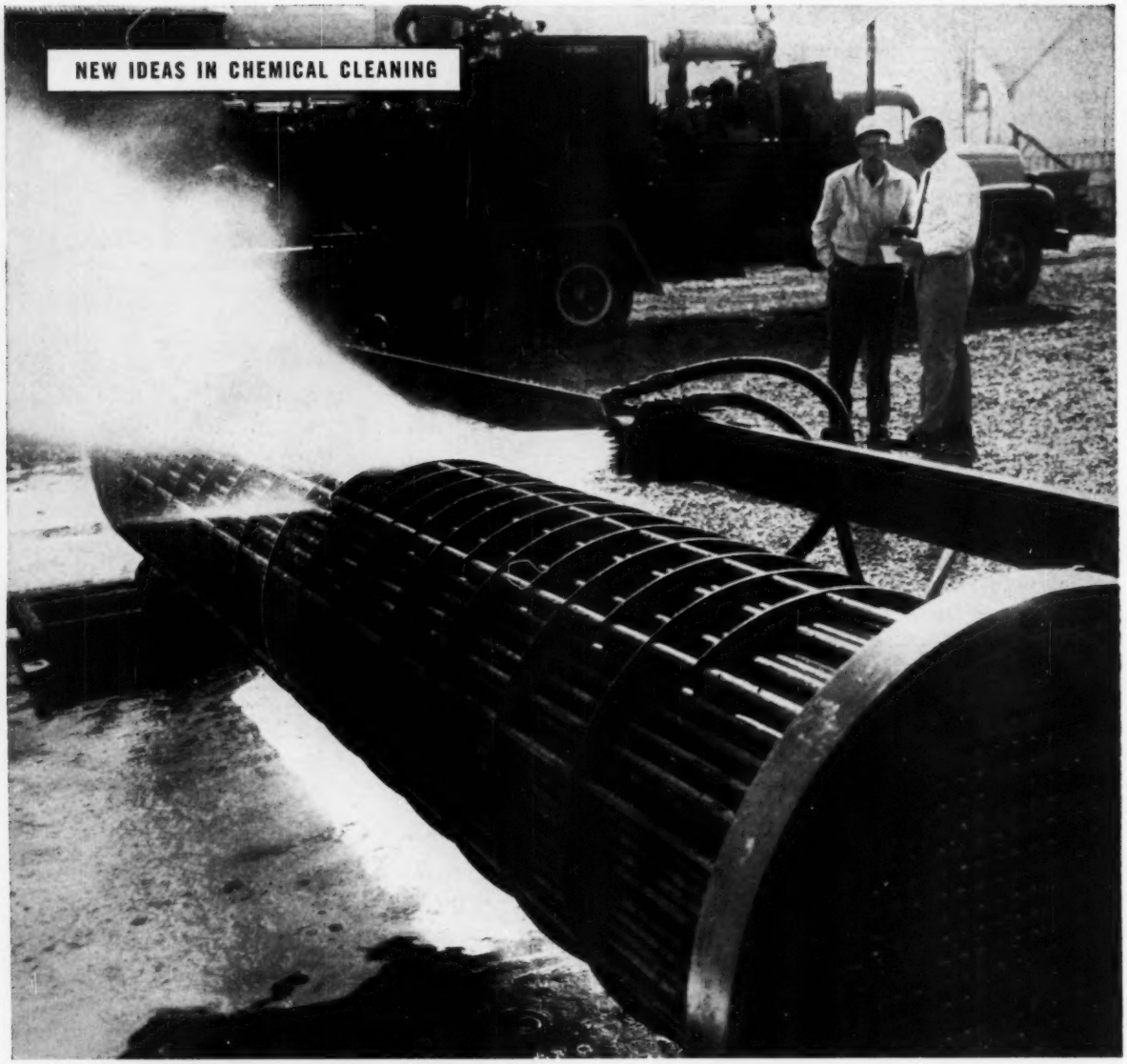

New Jetting Tool To Clean Tube Bundles Saves Thousands Of Dollars

The new high-pressure hydraulic tool, shown above, is currently saving thousands of dollars for companies in the refining, chemical, and petrochemical industries. It is the jetting tool developed by Dowell to remove deposits from heat exchanger tube bundles.

Previous methods of cleaning these bundles have been costly, time-consuming and often inadequate. Many times bundles had to be replaced completely because of the lack of a suitable cleaning method.

This new tool has a remarkable record of thorough, fast cleaning. For example, a slurry reboiler exchanger bundle, three feet in diameter and 16 feet long, was fouled with deposits of coke and asphalt. After being jetted from only one side, the bundle was thoroughly clean. Time required: less than one hour.

The tool holds the bundle in place for cleaning and has flanged rollers for rotation. The jet-head is manipulated automatically so that all tube spaces are covered. The jetted liquid can be either water or chemical solvents.

The new Dow Industrial Service Division will continue to offer the service which was formerly provided through the Dowell Division. For engineered recommendations to solve your cleaning problems contact the field office nearest you, or write Dow Industrial Service, 20575 Center Ridge Road, Cleveland 16, Ohio.

DOW INDUSTRIAL SERVICE

DIVISION OF THE DOW CHEMICAL COMPANY

DOW

A SPECIAL REPORT

SEPARATION METHODS

Selective Adsorption 125
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Superfractionation 139
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Thermal Diffusion 156

Latest Advances in Selective Adsorption

Some crystalline zeolites act as molecular sieves by adsorbing or rejecting molecules on the basis of their molecular size. See how these adsorbents can be used for octane improvement

G. J. Griesmer, H. B. Rhodes and K. Kiyonaga
Linde Company, Division of Union Carbide
Tonawanda, N. Y.

FROM A PETROLEUM refiners' standpoint, one of the most promising applications of selective adsorbents stems from the ability of some crystalline zeolites to either adsorb or reject molecules on the basis of their molecular size. Thus, the adsorbent acts as a molecular sieve.

One of these adsorbents can be made to adsorb normal paraffins while excluding isomers and cyclic hydrocarbons. When used in this way, the molecular sieve can be applied to separation steps in such octane improvement processes as isomerization, reforming and alkylation.

SOME PROCESS CYCLES

There are a number of ways in which molecular sieves can be used in fixed beds to separate and recover normal paraffins from iso and cyclic hydrocarbons. The choice will usually depend upon both the feedstock and the over-all processing scheme in which the separation step is to be integrated. Since desorption is usually the

SEPARATION METHODS
Selective Adsorption

most inefficient step in the cycle, the various process cycles differ primarily in the manner by which desorption is carried out. The major types of separation cycles are as follows:

Thermal Swing Cycles. A thermal swing cycle is defined as any cycle which employs different temperature levels for adsorption and desorption. The temperature of desorption is always higher than that for adsorption. A major feature of using a thermal swing cycle is that high design loadings can usually be obtained on the adsorbent. However, a cooling step must be considered as an additional item of expense.

Two methods for transferring the heat required to raise and lower the adsorbent temperature are by (1) direct and (2) indirect heating. An example of direct heating is the passage of hot gas through the adsorbent bed. In indirect heating, the heat transfer fluid does not come in contact with the solid adsorbent. The use of heating coils within a bed is an example of the indirect method. From a process standpoint, the methods differ primarily in the quantity and type of purge gas used, which in turn, affect the type and size of auxiliary process equipment required.

Pressure Swing Cycles. A molecular sieve separation process can be operated at close to constant temperature by conducting adsorption under pressure and desorption under a reduced total pressure. The operating temperature level should be sufficiently high so that upon a moderate pressure reduction, desorption will readily occur. For higher design loadings, vacuum desorption may be useful. This type of a cycle is simple because no heating and cooling steps are involved. Any heat requirements to maintain bed temperature may be provided by the adsorber feed stream itself.

Because additional time is not required for heating and cooling beds, the pressure swing cycle, as well as other adiabatic cycles, can generally be designed to operate in a more rapid cycle than thermal swing cycles. The rapidity of cycling is limited, among other factors, by the availability of quick-closing valves. A fast cycle materially reduces the adsorber dimensions and the molecular sieve inventory. In addition to the advantages of a rapid cycle, pressure swing cycles have the following features:

- Direct production of a high-purity normal paraffin product
- The ability to utilize gas compression as the main source of energy for the separation process.

A more completely described example of a pressure swing cycle is presented later.

Purge Gas Stripping Cycles. Purging a molecular sieve bed with a non-adsorbable gas will reduce the partial pressure of the adsorbed component in the vapor space and cause desorption to occur. The mechanism is similar to desorption by reduction in total pressure. For process consideration, the purge gas used for stripping an adsorbent bed may be classified as being either a condensable or a non-condensable fluid at normal operating conditions. In either case, the term "purge gas" as used here refers to a non-adsorbed or only slightly adsorbed fluid in order to distinguish it from the adsorbed fluids used in displacement desorption cycles.

Desorption of n-paraffins by gas stripping is usually followed by another processing step to separate the desorbate from the purge gas. If the recovered purge gas is to be recycled, it must be sufficiently free from *n*-paraffins to avoid readsorption on the molecular sieves.

Purge gas stripping becomes more efficient as the operating temperature is increased and the operating pressure is lowered. Because gas stripping works best at low pressures, the desorption step should be carried out at as low a pressure as economically possible. To increase the design loading, the adsorption step may be carried out at higher pressures or at temperatures lower than that of desorption.

A specific application of a non-condensable stripping gas is the possible utilization of recycle hydrogen, where the resulting mixture of *n*-paraffin and hydrogen can be fed directly to a conversion process.

The use of a condensable gas to strip the adsorbent beds is advantageous for the following reasons:

- Power requirements for fluid circulation are reduced substantially when a liquid pump instead of a gas blower or compressor is used to circulate the fluid through the furnace, heat exchangers, and adsorbers.
- The effluent stream may be condensed and the desorbed material separated from the purge fluid by simple distillation. Contamination of the circulating fluid by the desorbate can be readily controlled.

Displacement Cycles. Molecular sieve beds may be desorbed by the introduction of another adsorbable fluid which would displace all or part of the previously adsorbed material. Often in this type of a process, the displacement fluid must eventually be separated from both the *n*-paraffin as well as the iso and cyclic products. In those particular cases, the fluid must be readily separable from the process streams.

A significant manner of classifying displacement fluids is by the relative adsorptivities of the fluids with respect to the material being desorbed. Thus, a displacement fluid may be classed as either: (1) a more strongly adsorbed purge, or (2) a less strongly adsorbed purge. In either case, desorption is dependent on the relative adsorptivities of the components involved.

When a more strongly adsorbed fluid is used as the displacing agent, it will be immediately adsorbed on the molecular sieves, and so displace the less strongly adsorbed material that was on the adsorbent. Little or no partial pressure stripping action occurs. When a less strongly adsorbed fluid is used as the displacing agent, the desorption which occurs is due to both displacement and partial pressure stripping.

Generally, the more strongly adsorbed the displacing agent, the more complete the desorption of the previously adsorbed component, and the less the amount of displacing agent required. The use of a more strongly adsorbed displacement agent, however, introduces the problem of subsequently removing the agent from the

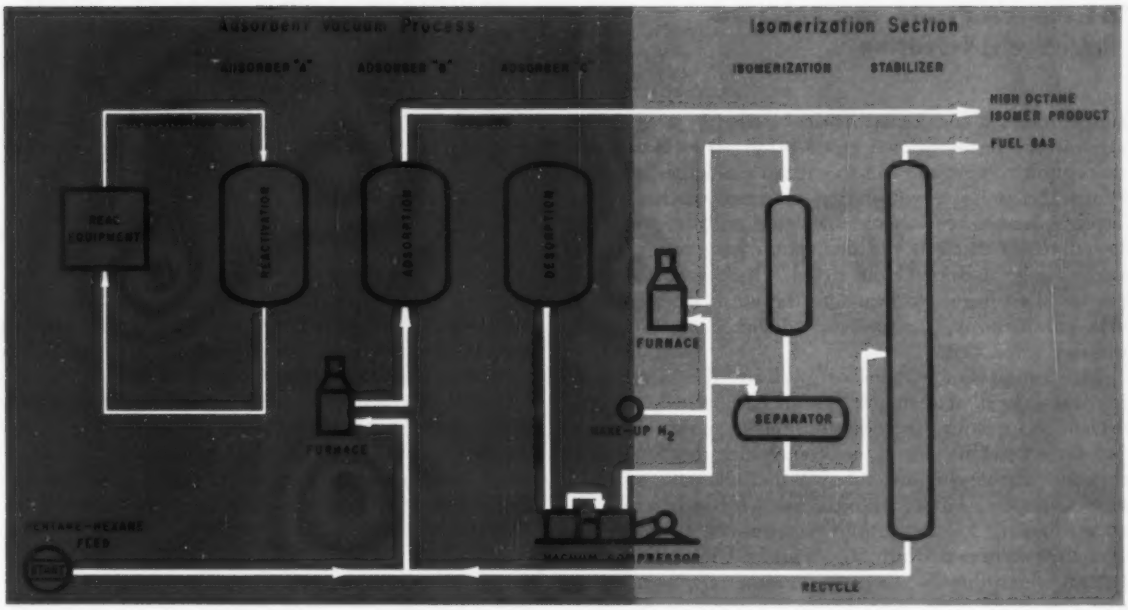

FIGURE 1—The selective adsorbent can be used in connection with a hydroisomerization plant with recycle to extinction of the normal hydrocarbons. The separation process is based upon an adiabatic fixed bed with vacuum desorption.

molecular sieves. If the bed is shifted to the adsorption phase without first desorbing the strongly held displacement agent, only a small portion of the displacement agent will be removed and the useful capacity of the bed will be sharply reduced.

There are several advantages in using a more strongly adsorbed purge cycle: (1) if properly operated, only a relatively small cleanup operation is required to remove the displacement fluid from the product streams, and (2) the cycle can be used for heavy end feed streams, since the displacement fluid can be chosen so that troublesome high boiling *n*-paraffins are removed at a relatively low temperature to suppress cracking. Displacement agents such as liquid water or ammonia could be used to accomplish the above objectives.

Although the use of a less strongly adsorbed gas as a displacement fluid entails a higher displacement gas circulation than that required with a more strongly adsorbed fluid, a major advantage accrues from its use. Removal of the displacement agent can usually be accomplished by displacement with the *n*-paraffins from the feed during the adsorption phase of the cycle.

A TYPICAL VACUUM PROCESS

In order to illustrate more fully a possible application of a selective adsorbent in octane-improvement processing, a specific process cycle was chosen to develop a preliminary design and economic analysis. A molecular sieve vacuum process was selected as a typical example.

This process was incorporated in a 4,000 bpsd pentane-hexane hydroisomerization plant with recycle to extinction of both *n*-pentane and *n*-hexane. A simplified flow diagram illustrating the basic processing steps with isomerization of the *n*-paraffin product is shown in Figure 1. The feedstock is a typical light naphtha containing 45 vol-percent normal paraffins.

The separation process is based upon an adiabatic fixed bed cycle with vacuum desorption. Adsorption is conducted under pressure and at a sufficiently high temperature so that subsequent desorption may be accomplished by reduction of total pressure. A detailed material balance is presented in Table 1.

Adsorption. Fresh feed is pumped to a preheater where it is heat exchanged with the hot non-adsorbed isomer product stream. The preheated fresh feed is combined with recycle reactor liquid product from the stabilizer of the isomerization section and fed to the adsorption heater. The combined feed to the adsorber is completely vaporized in the furnace and heated to 600° F under a pressure of 70 psig. The vapors are then fed to the adsorption vessel at 60 psig where the *n*-pentane and *n*-hexane are adsorbed selectively from the iso and cyclic hydrocarbons. During adsorption of the normal paraffins, the adsorber bed temperature increases to about 625° F from an initial 575° F due to heats of adsorption. The non-adsorped iso and cyclic constituents leave the adsorber and are condensed by exchange with fresh feed and cooling water.

Adsorption may continue until breakthrough of normal pentane in the product stream is detected either by temperature change in the adsorber bed or by a continuous stream analyzer. Because molecular sieves exhibit a stronger adsorptivity for *n*-hexane than *n*-pentane, all of the *n*-hexanes are adsorbed near the feed end of the vessel. At *n*-pentane breakthrough, therefore, there is virtually no *n*-hexane in the isomer product as shown in the detailed material balance. When *n*-pentane breakthrough occurs, the vessel is switched to the desorption phase and a freshly desorbed bed goes on the adsorption phase. By rapidly cycling the two adsorbers that are on stream, the entire operation is essentially continuous.

Desorption. Desorption is performed by first blowing down the bed from 60 psig to nearly atmospheric pres-

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sure through a constricted line controlled by a slow acting valve. The blowdown gas is arranged to bypass the desorption compressor and to enter a condenser directly. When the pressure within the adsorber reaches about 3 psig., the blowdown valve is closed and the gas is allowed to go through the desorption compressor via a vapor cooler and knock-out drum. The desorption compressor then begins to evacuate the adsorber. The normal paraffins are continuously desorbed as the total pressure is reduced.

The compressor chosen to perform the desorption operation is a six-cylinder, balanced-opposed, motor-driven reciprocating compressor. This compressor is a two-stage machine with three 38-inch diameter first-stage cylinders discharging into three 38-inch-diameter second-stage cylinders. All six pistons have a 14-inch stroke at approximately 330 revolutions per minute. All six cylinders are equipped with automatic suction valve unloaders which may be operated on either a time or pressure controlled cycle. The driver is a 1,000 horsepower synchronous motor. This is a conisderably smaller driver than is generally employed with a compressor of these dimensions. By partially unloading the compressor during a peak power requirement, a smaller driver may be used. The average horsepower requirement over the entire desorption operation is approximately 400 bhp.

During the evacuation period, the bed temperature drops to about 575° F. due to heats of desorption. When the total pressure within the adsorber reaches an average value of 1.0 psia, which corresponds to a suction pressure of 0.68 psia at the compressor, desorption is terminated by closing off the appropriate valves. At this point, a small quantity of isomer product leaving the adjacent adsorber, which is on the adsorption phase, is bled in from the top of the evacuated adsorber in order to repressurize the vessel. The direction of gas flow during the entire desorption phase is downward, i.e. opposite to the flow direction used during the adsorption phase.

The timing sequence selected for the cycle is as follows:

Steps	Minutes	Seconds
Adsorption	5	0
Desorption		
Blowdown	0	20
Valve changes	0	6
Vacuum desorption	4	18
Valve changes	0	6
Repressurizing	0	10
Desorption Total	5	0

Since only five minutes are allowed for the entire desorption step, which includes blowdown, evacuation, and repressurization, valve closure times, as well as tightness of closure, become extremely important considerations. Suitable valves up to 24-inch size are presently available. The designs have been thoroughly tested in butane and butene dehydrogenation units under similar temperature, differential pressure conditions, cycle times, and valve travel speeds.

Reactivation. As the two on-stream adsorbers continue to alternate between adsorption and desorption phases, a slow but measurable decline in adsorption capacity for normal paraffins occurs due to the accumulation of non-desorbable carbonaceous matter on the adsorbent. In order to restore the adsorption capacity of the adsorbent, it therefore becomes necessary to reactivate it when the differential loading falls to the design value. A spare adsorber is provided so that one vessel can be pulled off-stream and reactivated while the two remaining adsorbers are operating on the adsorption-desorption cycle. Since the adsorbers were designed to operate initially for 14 days of continuous cycling, one adsorber must be pulled off-stream and reactivated every seven days. However, near the end of a projected adsorbent life of two years, reactivation might be required after as few as six days of continuous cycling. Therefore, the equipment was sized to reactivate one adsorber every three days.

TABLE 1—Adsorbent Vacuum Process With Hydroisomerization

Component	POUND MOLES PER HOUR						
	Fresh Feed	Recycle Stream	Total Feed to Adsorber	Isomer Product	n-Paraffin Stream	Fuel Gas	Makeup Hydrogen
Hydrogen	.....	.....	.....	.....	.....	5.73	14.26
Methane	.....	.....	.....	.....	.....	3.62	1.34
Ethane	.....	.....	.....	.....	.....	1.89	0.67
Propane	.....	0.01	0.01	0.01	.....	8.41	0.51
i-Butane	.....	0.05	0.05	0.05	.....	0.30	....
n-Butane	0.58	0.32	0.90	0.80	0.10	0.31	....
i-Pentane	54.58	132.60	187.18	167.17	20.01	0.86	....
n-Pentane	122.01	94.34	216.35	8.20	208.15	0.09	....
Cyclopentane	.....	1.77	1.77	1.58	0.19	....	....
2, 2-Dimethylbutane	1.32	12.04	13.36	11.93	1.43	....	....
2, 3-Dimethylbutane	.....	10.48	10.48	9.36	1.12	....	....
2-Methylpentane	56.14	48.72	104.86	93.66	11.20	....	....
3-Methylpentane	39.42	35.51	74.93	66.93	8.00	....	....
n-Hexane	95.33	39.15	134.48	.....	134.48	....	....
Methylcyclopentane	64.27	13.60	77.87	69.56	8.31	....	....
Cyclohexane	24.45	2.28	26.73	23.88	2.85	....	....
Benzene	6.61	0.07	6.68	5.97	0.71	....	....
2, 4-Dimethylpentane	4.34	0.54	4.88	4.34	0.54	....	....
2-Methylhexane	5.92	0.70	6.62	5.92	0.70	....	....
Others	7.11	0.84	7.95	7.11	0.84	....	....
Total	482.08	393.02	875.10	476.47	398.63	21.21	16.78
Pounds Per Hour	39,162	30,653	69,815	38,656	31,159	601	95
BPSD	4,000	3,245	7,241	3,949	3,291	....	....

TABLE 2—Comparison of Estimated Capital Investments for 4,000-BPSD Hydroisomerization Plants (Gulf Coast Location)

Section of Plant	Isomerization With	
	Adsorbent Separation	Fractionation
Separation	$1,477,300	$2,002,300
Isomerization	842,700	842,700
Plant Investment	$2,320,000*	$2,845,000*
Adsorbent Inventory	237,800	.....
Isomerization Catalyst Inventory	75,000	75,000
Total Investment	$2,632,800	$2,920,000

* Without off-site facilities.

TABLE 3—Comparison of Estimated Manufacturing Expense for 4,000-BPSD Hydroisomerization Plants (Gulf Coast Location)

Utilities	Unit	$/Unit	ADSORBENT SEPARATION		FRACTIONATION	
			Consumption per CD[1]	$/CD[1]	Consumption per CD[1]	$/CD[1]
Steam	M lb.	0.40	124	50	2,100	840
Fuel	MM B.t.u.	0.20	752	150	288	58
Electric Power	kwh	0.008	14,000	112	8,280	66
Cooling Water	M gal.	0.01	4,200	42	9,849	98
Operating Labor						
2 Operators/shift	Man hr.	2.80	48	134	48	134
1 Supervisor/shift	Man hr.	3.75	24	90	24	90
Isomerization Catalyst Replacement[2]	lb.	3.70	30	110	31	115
Adsorbent[3]	lb.	1.00	326	326	....	....
Hydrogen Makeup	MM B.t.u.	0.20	106	21	89	18
Amortization[4]	....	....	....	645	....	791
Maintenance[5]	....	....	....	286	....	312
Insurance and taxes at 3%/yr. on plant investment	....	....	....	191	....	234
Interest at 3¼%/yr. on total investment	....	....	....	234	....	260
Overhead at 3%/yr. on plant investment	....	....	....	191	....	234
Royalty[6] (Isomerization)	....	....	....	90	....	90
TOTAL MANUFACTURING EXPENSE	....	....	....	2,672	....	3,340

[1] 90% on-stream efficiency.
[2] 100 bbl. of reactor feed/lb. catalyst.
[3] Two-year life.
[4] Based on an average rate of 10.15% per year for the first five years of a 15-year declining balance amortization calculation.
[5] 4½%/yr. and 4%/yr. on plant investment for adsorbent and fractionation, respectively.
[6] 5.7¢/bbl. of converted product.

TABLE 4—Cost Comparisons for 4,000-BPSD Hydroisomerization Plants (Gulf Coast Location)

	Isomerization With	
	Adsorbent Separation	Fractionation
Capacity, fresh feed, bpsd	4,000	4,000
RON of fresh feed, F-1 + 3cc TEL	88.5	88.5
Isomer Product		
Yield on Charge, vol-%	99.0	98.8
Research O.N. + 3cc. TEL	99.5	97.6
Total Investment, $	2,632,800	2,929,000
Manufacturing Expense, $/CD	2,672	3,340
Payout, after taxes, years	3.6	9.5
Return on Total Investment after taxes, %	24.2	7.6
Improvement Cost, ¢/Octane-Barrel	8.6	12.7

Basically, the reactivation procedure used in this design is similar to that generally used to reactivate platinum reforming catalysts. Certain precautions were taken in designing the reactivation equipment in order to insure that molecular sieve crystal destruction would not occur. These included maintaining a minimum partial pressure of water vapor over the bed at reactivation temperatures and preventing combustion temperatures from exceeding about 1,000° F. The reactivation procedure involves three steps:

1. heating the adsorbent to the initial reactivation temperature of 750° F by means of hot inert gas circulation,
2. burning the carbonaceous matter by controlled addition of oxygen,
3. cooling the adsorbent back to its initial adsorption temperature of 575° F by inert gas circulation.

The heating step serves a dual function. In addition to heating the bed, the hot gases are used to strip off the desorbable residual hydrocarbons as well as to decompose a portion of the carbonaceous deposit. The inert gas within the system is continuously recirculated to heat the bed to 750° F while a bleed stream of effluent gas is continuously removed to deplete the circulating gas gradually of desorbed hydrocarbons. The inert gas generator operates throughout the heating step.

The makeup gas is dried in a molecular sieve drier before being fed to the reactivation gas system. The dew point of the gas entering the adsorber is maintained at a maximum of 40° F. When the vessel is brought to the reactivation temperature, the burning step is begun.

The inert gas generator is shut down and a controlled amount of air is added to the circulating inert gas stream to provide about 0.5 to 1 percent oxygen mixture. The entire reactivation gas is now passed through the drier and heated to 750° F before being fed to the adsorber. The moisture entering with the air and the water vapor produced during the burnoff is removed in the drier.

Because of the low relative humidity of the gas entering the drier, the drying capacity of conventional desiccants such as silica gel and activated alumina is low. Molecular sieves, on the other hand, have high capacities under such conditions and are therefore ideally suited for this application. After the burning front passes out of the adsorber, the oxygen content at the adsorber inlet may be gradually increased up to about 21 percent to effect a final cleanup.

For the cooling step, the inert gas generator is again placed in operation. The recirculating gas is now heated to 575° F, the temperature at which adsorption is resumed, before it is fed to the adsorber. To purge the system of oxygen remaining from the burnoff step, part of the recirculating gas is continuously vented to the atmosphere while dry makeup inert gas is added. The recirculating gas is allowed to bypass the drier during this cooling step and only makeup inert gas is dried.

The approximate time sequence selected for the minimum reactivation time of three days is as follows:

Steps	Hours
Preparation (including vacuum breaking, hand block valve operation, checking, etc.)	1
Heating phase	15
Burning with 0.75% oxygen	42
Cooling phase	13
Preparation	1
Total	72

ECONOMICS

Cost estimates and economic data for a molecular sieve vacuum process installation were prepared by the

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Foster Wheeler Corporation. Similar estimates were obtained for a fractionation case to provide an approximate economic yardstick. This case was also designed on the basis of recycling and isomerizing both *n*-pentane and *n*-hexane to extinction. In order not to penalize unduly the fractionation process, too precise a fractionation was avoided, and a looser separation than that obtained with selective adsorbent was chosen.

Capital Estimates. A breakdown of the capital investments for the 4000-bpsd pentane-hexane isomerization plants in Table 2 shows the plant investment for the adsorbent process is $525,000 less than the fractionation plant investment, and this cost differential is entirely between the separation sections of the respective plants. The adsorbent inventory of 237,800 pounds has been charged at $1 per pound, while the isomerization catalyst inventory is the same for both plants. The adsorbent process has an advantage of nearly $300,000 in total investment.

Manufacturing Expenses. Table 3 contains a comparison of the estimated manufacturing expense of each process. The adsorbent process has a substantial daily saving of $668.

Cost Comparisons. The results of the economic study shown in Table 4 clearly favor the adsorbent separation which produces a product quality of approximately two octane points higher than fractionation at a significantly lower cost. The production of a higher quality product obtained at both a lower total investment and a lower manufacturing expense has been evaluated as a Research-octane-barrel improvement cost of 8.6 cents. This cost is approximately 4 cents per octane-barrel lower than the cost of the fractionation route.

DESIGN INFORMATION

The design of a molecular sieve separation process requires a knowledge of the equilibrium and mass transfer relationships of the adsorbable components in the feed. The effects of processing conditions and the character of the feed on the cyclic performance of the adsorbent must also be known. When used for hydrocarbon separations, molecular sieves generally suffer a slow loss of adsorptive capacity over an extended period of operation. The deactivation is usually due to a buildup of a deposit of carbonaceous material. The capacity lost, however, can be regained by the proper reactivation procedure which includes high temperature purge with an inert gas and/or burnoff. The following discussions presents a summary view of the experimental information required for process design:

Equilibrium. Pure component equilibrium loadings on an adsorbent are expressed as a function of temperature and pressure. The familiar adsorption isotherm results when the loadings are determined by varying pressure at constant temperature. Normal hexane isotherms for one adsorbent are shown in Figure 2. They are distinguished by relatively high loadings over a wide range of operating temperatures and pressures.

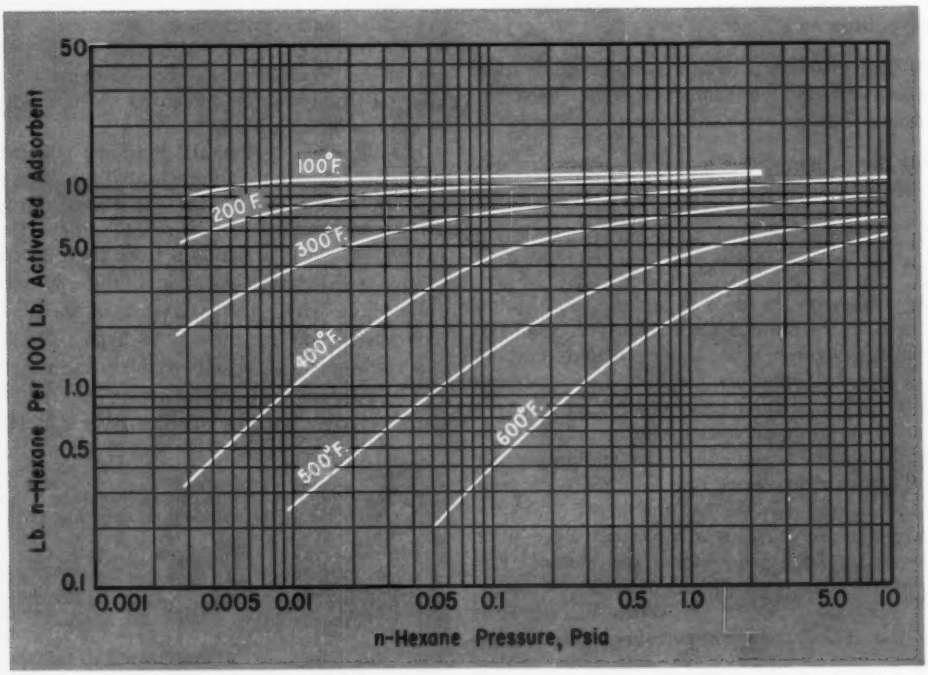

FIGURE 2—High loading of normal hexane on one type of adsorbent can be obtained over a wide range of operating temperatures and pressures.

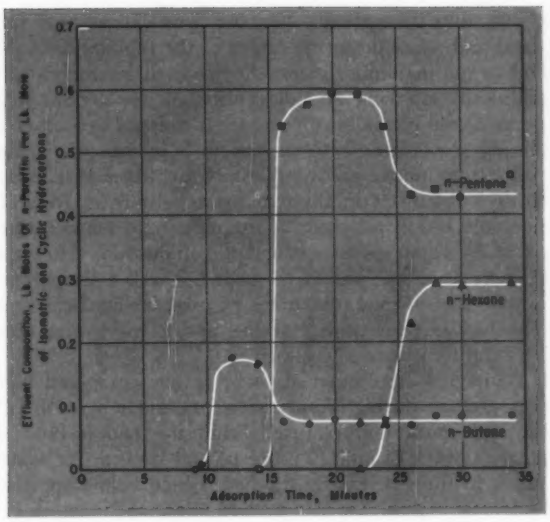

FIGURE 3—Effluent composition of a multicomponent stream varies with time. Here are data for a mixture of normal butane, normal pentane and normal hexane when light naphtha is fed at 600° F and 14.7 psia.

Multicomponent equilibrium data involve not only adsorbate loadings, but also adsorbate composition, determined at a given temperature and pressure. The adsorbent used here is highly selective for normal paraffins in the presence of their isomers and cyclic hydrocarbons. It will accept only those molecules having a critical dimension less than about 5 angstrom units. Isoparaffins and cyclic hydrocarbons are therefore excluded by their physical size. The composition of the adsorbate within the molecular sieve crystal is determined by the relative adsorptivities (separation factors) and vapor phase concentrations of the adsorbable molecules only. However, it is important to note that, in octane improvement processes, the adsorption which takes place within a pellet, external to the molecular sieve crystals, may be non-selective for the normal paraffins. The total adsorbate on the pellet may, therefore, contain some small amount of branched-chain and cyclic hydrocarbons. A typical illustration of the magnitude of this effect at 570° F and 75 psia is given for light naphtha equilibria in Table 5.

The adsorption of hydrocarbons on molecular sieves occurs by a physical adsorption mechanism. The associated enthalpy change, although generally small compared with the heat changes which take place in chemical reaction, is nevertheless important in designing commercial adsorption processes. Isosteric heats of adsorption have been calculated from normal paraffin equilibrium data giving values in the range of 300 to 400 Btu/lb. of *n*-paraffin adsorbed.

Mass Transfer. When a feed gas containing an adsorbable component is fed to a bed of activated molecular sieve, adsorption usually occurs in a steady state mass transfer front or wave. The transfer front forms at the feed end of the bed and then progresses through the bed, maintaining a constant length and fixed shape. The character of the moving front depends on the feed rate, the operating temperature, and the nature of the adsorbable component and its partial pressure in the feed gas. When the feed contains more than one adsorbable component, a number of mass transfer waves are formed. A chromatographic type of separation takes place with the more selectively adsorbed component concentrated at the feed end of the bed.

The composition of a hydrocarbon stream leaving a molecular sieve bed as a function of time is shown in Figure 3 for multicomponent adsorption of *n*-butane, *n*-pentane, and *n*-hexane from a light naphtha feed.

Deactivation. The gradual buildup of a deposit on molecular sieve pellets is a complex phenomenon involving a number of steps. For example, normal paraffins exposed to the adsorbent surface at elevated temperatures may both isomerize and crack to an olefin plus a one- or two-carbon saturate. The isomer, which is too large to escape, may be entrapped in the crystal cavity and thus reduce capacity. The isomer is also subject to further cracking and polymerization. The olefin being strongly adsorbed will tend to remain on the adsorbent. Depending on the temperature, the olefin then polymerizes and/or condenses to an aromatic with a further loss of hydrogen. This deposit remains on the adsorptive surface, thereby further reducing the adsorption capacity.

Experimental data have shown that the percentage loss of equilibrium adsorption capacity due to a par-

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ticular carbonaceous deposit is a characteristic of the deposit, and is independent of the normal paraffin adsorbate or the adsorption conditions. For example, a sample of adsorbent containing 1.7 pounds of carbon per 100 pounds of activated adsorbent with a hydrogen-to-carbon ratio of 1.68 suffered a constant loss of 18 percent of equilibrium capacity for *n*-butane at 75° F over a *n*-butane partial pressure range of 0.0025 to 18 psia. This same sample showed a *n*-hexane equilibrium capacity loss of 15 percent measured at 300° F and a *n*-hexane partial pressure of 2.7 psia. In addition, it has been determined that the carbonaceous deposit does not affect the absolute rate of adsorption of *n*-paraffins. The presence of the deposit, with the attendent loss in equilibrium capacity, acts merely as a diluent in the bed. The length of bed required to contain the mass transfer front is therefore inversely proportional to the fraction of original equilibrium adsorption capacity retained.

Typical deactivation rates for various process cycles, range from 0.3 percent of fresh bed equilibrium capacity lost per 100 cycles of operation to as high as 25 percent of capacity lost per 100 cycles. These deactivation rates were determined with naphtha feeds with end points ranging from 170° to 250° F. Based on a total cycle time of only 10 minutes and a loss of 25 percent of initial adsorption capacity, these deactivation rates would correspond to onstream periods of from one day to several months between reactivations. No experimental data are available for guard bed operation.

Reactivation. The reactivation of a molecular sieve adsorbent bed is similar to the regeneration of catalyst beds widely practiced in the petroleum industry. However, during the burnoff step, particular attention must be given to the temperature level and water vapor concentration within the bed. The molecular sieve crystal may be damaged by excessively high temperatures and exposure to high moisture concentrations over extended periods of time.

The molecular sieve bed is initially heated above the ignition temperature (about 700°-750° F) and purged with inert gas. This removes desorbable material and reduces both the quantity and the hydrogen content of the deposit to be burned. A stream containing about 0.5-2 percent oxygen is then introduced. A stable burning zone with a constant maximum temperature at its leading edge forms and moves through the bed. Inert gas passing through this burning zone carries heat forward and raises the temperature of the remainder of the bed to the maximum value. At this higher temperature, additional cracking and desorption of the deposit may occur ahead of the burning zone. A residual deposit containing somewhere between 0.5 to 3 pounds of carbon per 100 pounds of activated adsorbent with a H/C atom ratio of about 0.9 usually remains to be burned. In addition, the bed is exposed, at the maximum temperature, to water vapor as a product of combustion. After the burning zone has passed through the bed, a 21 percent oxygen stream may sometimes be used for final cleanup. The bed is then cooled to the normal operating temperature for return to cycling.

Damage to molecular sieve by water vapor and high temperature during a burnoff is extremely slow if (1) the maximum temperature within the bed is held to about 1,000° F, and (2) the partial pressure of water vapor in the gas leaving the bed is held below approximately 0.1 psia. Operation within these limits is obtained by drying the entering burnoff gas and selecting the proper oxygen concentration for the particular deposit being burned. General heat and material balance equations have been developed which allow ready calculation of this concentration and also the time required for burnoff. Data on burning rates useful for estimation of the width of the burning zone are also available.

Adsorbent Life. In order to determine the effect of repeated reactivations on the life of the adsorbent, an accelerated aging test was carried out in which a molecular sieve bed was subjected to 34 burnoffs. A deposit of 2.4 pounds of carbon per 100 pounds of activated adsorbent at a H/C atom ratio of 0.9 was removed during each burnoff. A maximum temperature of 1160° F was reached in the bed. It was found that the equilibrium capacity of the bed dropped 5 percent over the first several burnoffs, and then remained constant at this level for the remainder of the test. The bed was then placed in normal paraffin adsorption service. It was operated for 5800 thermal swing adsorption-desorption cycles with a light naphtha feed. The cyclic performance was found to be unchanged from that of a bed which had never been subjected to reactivation.

Data have also been obtained for extended periods of cyclic processing of light naphtha feed stocks with end points up to 250° F. These tests range from a 3,200-cycle run with pressure swing desorption and two reactivations to a 15,000-cycle run with thermal swing desorption and 13 reactivations. The results suggest that changes in the long-term performance of the adsorbent due to adsorption-desorption cycling of naphtha feeds are small compared with changes due to the reactivation technique. Combination of these results with the results of the reactivation studies previously described indicates that a molecular sieve bed should give satisfactory performance for several years of operation in octane improvement service. ##

TABLE 5—Light Naphtha Equilibria

Components	Vapor Composition, Mole—%	Adsorbate Composition, Mole—%	Lb. Adsorbed Per 100 Lb. Activated Adsorbent
Isopentane	10.3	0.4	0.02
n-Pentane	24.1	30.2	1.63
Isohexanes	21.6	1.9	0.12
n-Hexane	19.5	54.4	3.51
Methylcyclopentane	10.4	0.2	0.01
Isoheptanes	5.1	0.6	0.07
Cyclohexane	4.0	0.4	0.03
n-Heptane	5.0	11.9	0.89
Totals	100.0	100.0	6.28
Total *n*-Paraffins	48.6	96.5	6.03

Latest Advances in Membrane Permeation

From lab and economic data, you can see how close this unit operation is to commercialization. It's a fast-breaking process

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MANY POLYMERIC MEMBRANES can be permeated by fluids, and many membranes permit easier passage of one fluid than of another. So, the composition of a fluid mixture may be changed by allowing a portion of the mixture to pass through a selective membrane. This constitutes the principle of a useful separation process.

In one adaptation of the process, the membrane is contacted by gaseous or vapor mixtures. However, recently, extensive research concerning the separation of liquid mixtures has been conducted at the American Oil Company research laboratories, and presently by its licensee, Ionics, Incorporated. Separation of liquid mixtures is achieved with the upstream face of the membrane in contact with liquid, the permeated fraction being removed on the downstream face as vapor.[3,6,7,8]

Sufficiently high separating factors and permeation rates have been obtained so that the process now should be of commercial interest especially for these applications:

1. Separation of azeotropes and close-boiling mixtures of water and oxygenated hydrocarbons such as alcohols, ketones, ethers, aldehydes, acids, etc.

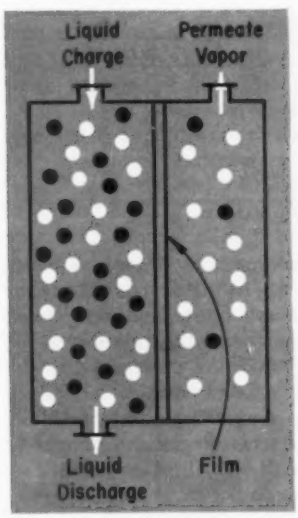

FIGURE 1—Membrane is selective toward component B.

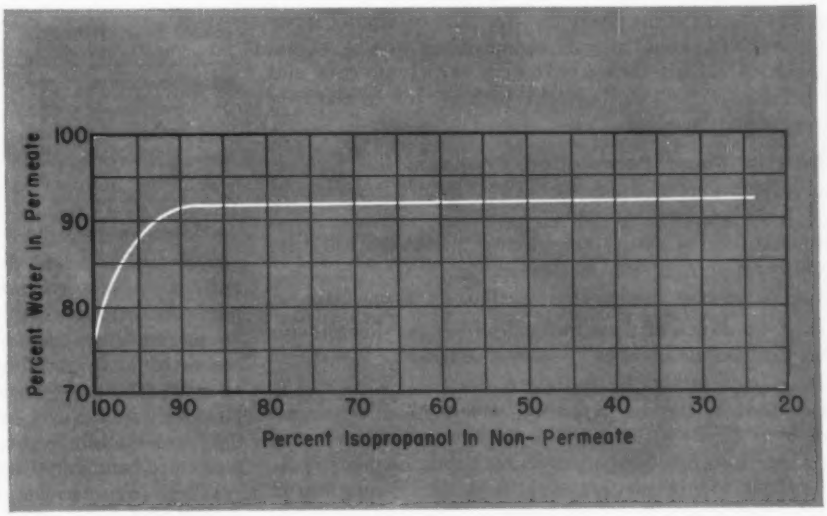

FIGURE 2—For water-isopropyl alcohol system, the permeate averages a constant 92 percent water for a wide range of alcohol concentrations in the non-permeate.

2. Breaking of azeotrope of water and ester, alcohol and ester, and/or shift of equilibrium in esterification reactions by continuous water and/or alcohol removal.

3. Separation of azeotropes and close-boiling mixtures involving water and miscellaneous materials such as aromatic hydrocarbons, nitriles, amines, etc.

4. Recovery of amines, such as pyridine, from dilute aqueous solutions.

5. Separation of different types of organics from each other (e.g., aromatic from alicyclic and/or aliphatic hydrocarbons); oxygenated from non-oxygenated hydrocarbons and vice versa; possibly also separation of different species of organics (e.g., alcohols and aldehydes; hydrocarbon isomers, etc.).

Some of these applications are ready for immediate commercialization, while others require further investigation. This includes among other things extension of the data into concentration ranges not previously covered by experimentation as well as determination of film life. At present, Ionics, Incorporated, has several programs under way aimed at answering such unknowns.

It should be emphasized that membrane permeation should be regarded above all as a unit operation. For example, frequently economics will dictate recovery of both permeate and non-permeate. Sometimes this can be done by a second or third membrane permeation stage, but often it will be economical to resort to conventional means, such as distillation, for secondary recovery. For example, instead of concentrating a component in a mixture by membrane permeation from 70 to 99%, it may be economical to use membrane permeation to concentrate to 85% only, e.g., to break an azeotrope, and to concentrate the effluent further by distillation to yield pure product at one end and azeotrope at the other. The azeotrope may be recycled to the permeation unit. Certainly, secondary recovery practically always will be necessary in the case of hydrocarbon separations. Thus, stream compositions can be tailor-designed to suit the customer's requirements and optimization will be required with regard to the best economic procedure.

Description of Permeation Process. The process of permeation of fluids through polymers is composed of these independent steps:

1. Solution of the permeating molecules into the upstream face of the membrane,

2. Diffusion of these molecules through the membrane,

3. Evaporation of these molecules from the downstream face of the membrane.

In general terms, the process under consideration was described by Binning & James[4] and is shown schematically in Figure 1. This figure shows a permeation unit, divided into two compartments by a film, or membrane. As depicted, the charge comprises a liquid mixture of 50% component A (black circles), 50% component B (white circles). The feed enters the left compartment as shown in the diagram, and is kept in the liquid phase during permeation. Permeate passes through the membrane and is vaporized; the membrane as depicted is selective toward component B and the mixture in the compartment to the right of the membrane analyzes 80% B, 20% A.

The ease of separating mixtures by permeation can be expressed in terms of a separation factor, α, defined as the concentration ratio of B/A in the permeate divided by the ratio of B/A in the liquid phase, or

$$\alpha = \frac{y_B}{y_A} \Big/ \frac{x_B}{x_A}, = \left(\frac{x_A}{x_B}\right)\left(\frac{y_B}{y_A}\right) \qquad (1)$$

where x_B = concentration of B in the liquid
y_B = concentration of B in the permeate, etc.

In the case illustrated in Figure 1 and assuming that the quantity permeated was sufficiently low in relation to the amount fed so that the composition of the charge remained essentially constant, so that x_A is 50, x_B is 50, y_A is 20, y_B is 80, the separation factor, α, is

$$\left(\frac{50}{50}\right)\left(\frac{80}{20}\right) = 4$$

In the course of investigations involving a wide variety of separations under many different operating conditions, essentially two types of results were obtained. In one type, α is a constant over a wide range of liquid compositions. In the other, the permeate composition and, hence, the ratio y_B/y_A remains constant; accordingly, α varies over a wide range of liquid compositions. The foregoing may be explained by recalling that permeation involves solution of a component in the film (or solubility) as well as diffusion; hence, it is likely that in the case of a constant α diffusivity, and in the case of a constant permeate composition solubility constitutes the process-controlling factor.

As permeation proceeds, the non-permeating liquid is continuously enriched in component A. Table I shows the difference in results depending on which factor is controlling.

TABLE 1—Effect of Selectivity-Behavior on Permeate Composition

	Constant Separating Factor (Changing Permeate Composition)		Constant Permeate Composition (Changing Separating Factor)	
x_A	α	y_A	y_A	α
.1	4	.027		
.2	4	.059	.20	1.0*
.3	4	.097	.20	1.7
.4	4	.143	.20	2.7
.5**	4	.200	.20	4
.7	4	.37	.20	9.3
.9	4	.69	.20	36
→1.0	4	→1.00	.20	→∞

* Limiting feed mixture 20% A since $\alpha = 1$.
** Case illustrated in Figure 1.

When it is desired to recover pure B (the preferentially permeating component), in the case of a constant permeate composition recovery must be accomplished by means other than permeation: the mixture to be recovered analyzes 80% B and the permeate likewise analyzes 80% B, so that no further separation is effected. However, in the case of a constant separating factor, the permeate can be successively restaged and ultimately a mixture containing essentially B will be obtained.

Where (non-permeating) component A constitutes the desired end-product, permeate reprocessing becomes a factor of increasing importance as its concentration in the permeate increases. For instance, in concentrating the 50/50 feed used in the preceding example to 90%

A, 10% B, in the case of constant α the permeate will average 45% while in the second case it remains a constant 20% A.

To illustrate further, experimentally it was found that separation of water and isopropyl alcohol, using a given film, yields a constant permeate composition of 92% water as the alcohol is concentrated from 25% to 92% while during further concentration the alcohol content in the permeate increases (Figure 2). In concentration from 92% to 97%, the permeate from an aqueous methyl ethyl ketone mixture averaged a constant 98.5% (Figure 3-a) while in the case of ethyl alcohol a constant separating factor resulted (Figure 3-c). By material balance, it can be calculated that for every pound of 97% nonpermeating product, one should charge 1.05 pounds of 92% MEK and will permeate 0.05 pounds of 98.5% water, or 1.14 pounds of 92% EtOH yielding 0.14 pound of permeate averaging 56.5% water.

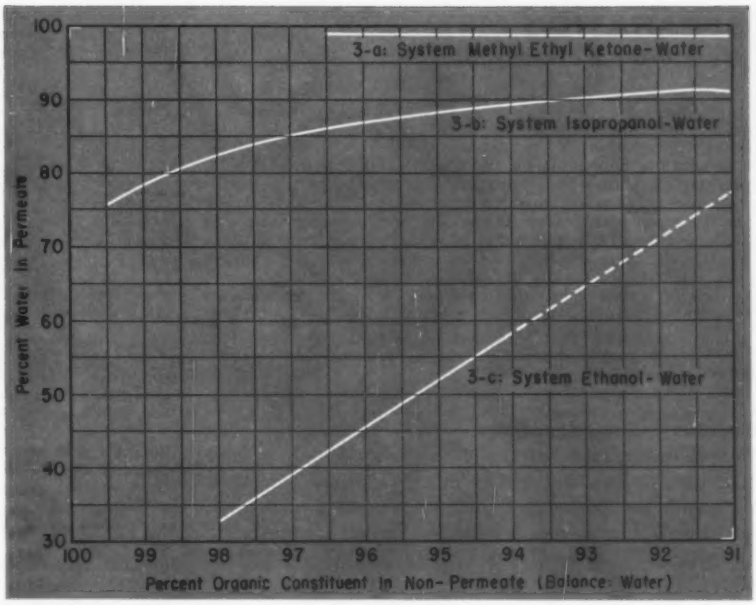

FIGURE 3—Separation varies for each organic as shown in these organics-water data by membrane permeation.

Generally, it may be stated that if the desired pure product constitutes the larger proportion of the feed, it is preferable economically if it constitutes the nonpermeating component. If the desirable product constitutes the smaller portion of the feed, it may be preferable if it constitutes the permeating component. Where the permeate is then condensed for the second stage permeation, the desired product again may permeate preferentially. On the other hand, there are instances where by change of films permeability can be reversed so that the non-desired component is now permeated preferentially and the second stage permits the desired product to be recovered in the non-permeating fraction.

Present Status of Membrane Permeation. A batch-type permeation cell having ten square feet of membrane surface has been operated for many months by American Oil Company. Thus, the process already has been tested and proven well beyond bench scale. More recently, Ionics, Incorporated, has engineered a continuous-flow pilot-size membrane permeation cell having 20 square feet of membrane surface. An automated continuous-process pilot plant, designed around this prototype equipment, has been started up. This equipment is suitable for scale-up: initially, commercial-size cells containing approximately 1,000 square feet of membrane surface are visualized, manifolded where larger surface areas are required.

Meantime, in addition to batch pilot plant data on the concentration of an aqueous ethanol-isopropanol mixture,[4] laboratory data have been obtained on numerous separations, of which several are discussed:

Concentration of Ethanol. Data obtained to date yield a cost picture that is identical both from operating and investment standpoint to the cost of conventional dehydration by benzene azeotroping. Therefore, with additional development work this may well become an important application for membrane permeation especially in areas where steam cost is high.

Concentration of Isopropanol and Other Alcohols. To date, constant permeate compositions of well over 90% water have been obtained over a wide range of feed compositions (Figure 2). Typical permeation rates are 3-5 pounds per hour per square foot at 50% water in feed, decreasing to 0.4 pounds per hour per square foot at 10% water in feed. As will be illustrated later, the cost of concentrating these materials from, say, 90% to 99+%, is projected to be approximately $0.002 per pound.

Concentration of Ketones. The permeate in concentrating methyl ethyl ketone from 90 to 98% analyzed a constant 98+% water (Figure 3-a). This means that for every pound of MEK (non-permeate) produced only about five-hundredths of a pound of material analyzing essentially water will have to be evaporated. An operating cost of approximately $0.001 per pound is envisioned for this application.

Concentration of Dioxane. Extremely high selectivity and high permeation rates (1 pound per hour per square foot at 12% water in feed) have been obtained in the laboratory.

Concentration of Acetonitrile. Laboratory data on this potential application look extremely promising and economical.

The same comment holds for the concentration of **formic acid, acetic acid, pyridine, butylamine,** etc.

Concentration of Formaldehyde. Thus far, formaldehyde has been concentrated successfully from 17 to 60%. Over this range, permeation rates are very high (3-5 pounds per hour per square foot) but selectivity has been only fair to the point that, at the present state of the art, the cost of membrane permeation is about equal to the cost of alternative concentrating procedures. If selectivity can be improved even a little, this should become an important commercial application.

Dehydration of Reaction Mixtures. Organic acids and alcohols undergo catalytic reactions to form esters and water. The products and reactants form an equilibrium mixture, and either water or the ester must be removed to complete the reaction. Industrially, after one of the products is removed to complete the reaction, secondary recovery and purification of the ester are invariably required. However, permeation may be used to separate water to complete esterification and simplify secondary recovery. This has been tested successfully in the laboratory on a butyl alcohol-acetic acid reaction mixture and by concentrating methyl acetate.

Hydrocarbon Separations. Normally in hydrocarbon separations, one does not require recovery of any one pure component, but

rather one wishes to obtain hydrocarbon blends. By membrane permeation it is almost possible to tailor-make a separation, depending on the desired application. For example, starting with a 50/50 mixture of n-heptane and iso-octane, 57% n-heptane was permeated at a rate in excess of 10 pounds per hour per square foot. It also has been possible instead of 57% to obtain 90% n-heptane in the permeate; however, permeation rate here was less than 0.1 pounds per hour per square foot. This is an extreme illustration of the fact that the economics of applying membrane permeation to hydrocarbon separations should be examined for each case.

It is noteworthy that separation of xylene isomers has been investigated in the laboratory and that in principle this application looks feasible.

Economic Considerations. In addition to the usual factors that affect the cost of any process such as labor and utility rates, the factors that govern the economics of membrane permeation include permeation rate and selectivity. The former is reflected principally in capital investment: in general, for a given required output, the faster the permeation rate, the less membrane surface area will be required, and capital cost is almost a direct function of membrane surface. On the other hand, selectivity governs the process material balance and therefore affects both capital investment (via membrane surface area) and operating cost.

If for every W pounds of non-permeate product, there are V pounds permeated, then for every pound of non-permeate product, the permeate will be V/W pounds and the feed will be (V+W)/W pounds. If the permeation rate is R pounds per hour per square foot, it follows also that V/(WR) square feet of membrane surface are required per pound non-permeate product per hour.

Note also must be made of the fact that the feed generally is preheated but that only the permeate is vaporized. The process as envisioned is continuous, the heart being a permeation cell. With this in mind, economics now may be analyzed as:

Labor. One-fourth man/hour per 1000 ft.² of membrane surface or fraction thereof appears to be a reasonable projection at present. In general terms, at a labor rate of D dollars per hour, this becomes:

$$\$ (2.5 \times 10^{-4}) \frac{DV}{WR} \text{ per pound of product}$$

Example: Let D = \$3/hour
Let R = 0.4 lbs/hr-ft.²
Let W = 1000 lbs/hr
Let V = 400 lbs/hr (V/W = 0.4)

$$\text{Labor will be } \$ 2.5 \times 10^{-4} \frac{(3)\ (400)}{(1000)\ (0.4)} = \$0.00075 \text{ per pound}$$

Supervision. One-eighth supervisor is a reasonable assumption. At E dollars per hour this is 0.125 E/W dollars/pound.

Example: ⅛ supervisor @ \$4.50/hour and W = 1000 gives \$0.00056 per pound.

Overhead and Laboratory. Every company has its own standard accounting practices for these items, which will apply here also.

Supplies and Maintenance. Supplies essentially will consist of membranes, which periodically will have to be replaced. Membranes—discussed in somewhat greater detail later in this article—cost no more than a few cents per square foot. Although it is still too early accurately to project membrane life for the many diverse applications that are envisioned, experimentally membranes have stood up for over 5,000 hours (seven months) of continuous operation, and even then did not suddenly fail, but gradually had begun to exhibit some decreased selectivity (Figure 4). Therefore, it should be conservative to project a membrane life of 2000 hours. Correspondingly, maintenance essentially will consist of equipment disassembly and reassembly for membrane replacement. If we estimate it will take one man-hour per 2000 operating hours per 10 square feet of membrane, we get:

1 man-hour per 10 ft.² per 2000 hours, at a maintenance rate of G dollars per hour; this becomes $(5 \times 10^{-5}) \frac{GV}{WR}$ dollars per pound of product.

Example: Let G = \$3/hour, R = 0.4 lbs/hr-ft.², V/W = 0.4; Maintenance cost becomes $\$ (5 \times 10^{-5})\ (3) = \$0.00015$ per pound.

This figure is a tentative estimate and the standard maintenance costs for piping, heat exchangers, pumps, etc., should be added, but it is seen that even a factor of ten increase in maintenance cost would not affect the practicability of the process. Note also that film cost may be ignored, for at a cost as high as ten cents per square foot in the above example it would add \$0.000005 per pound.

Steam. Evaporation: Let L_v = average latent heat of permeate
S = cost of steam, dollars per million Btu

Per pound of non-permeate produced, V/W pounds of permeate are vaporized, or:

Evaporation cost = $(S \times 10^{-6})\ (L_v)\ (V/W)$ dollars per pound of product. If we assume 1 pound of steam yields 833 useful Btu's, the above expression may be written also as:

Evaporation requirement: $(1.2 \times 10^{-3})\ (L_v)\ (V/W)$ pounds of steam per pound of product.

For the removal of water from organics, assume $L_v = 833$, so that: evaporation requirement is V/W pounds of steam per pound of non-permeate product.

For hydrocarbon or straight organics separations, assume $L_v \approx 300$, so that evaporation requires (0.36V)/W pounds of steam per pound of non-permeate product.

Steam. Preheat. Although some steam may be required to preheat the feed, heat exchange may be effected with either the non-permeating liquid or with the permeate or with both. Consequently, the preheat steam requirement is negligible. Likewise, although there will be occasions where the permeate will be vaporized under reduced pressure, ejector steam cost will not be a factor of importance.

Other Utilities. Less than 10 hp will be required to move the material through a one-thousand square foot permeation cell. Typically, such a cell may produce one-thousand pounds per hour of product; consequently, electrical requirements are negligible on a per pound basis. Likewise, cooling water requirements may be ignored.

Figure 5 shows projected operating cost as a function of

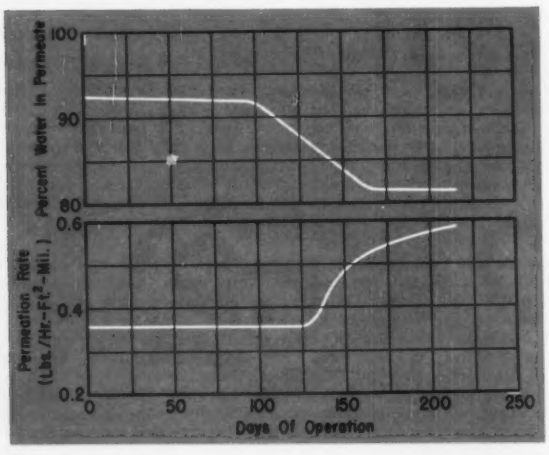

FIGURE 4—Membrane life is demonstrated in this isopropanol-water system.

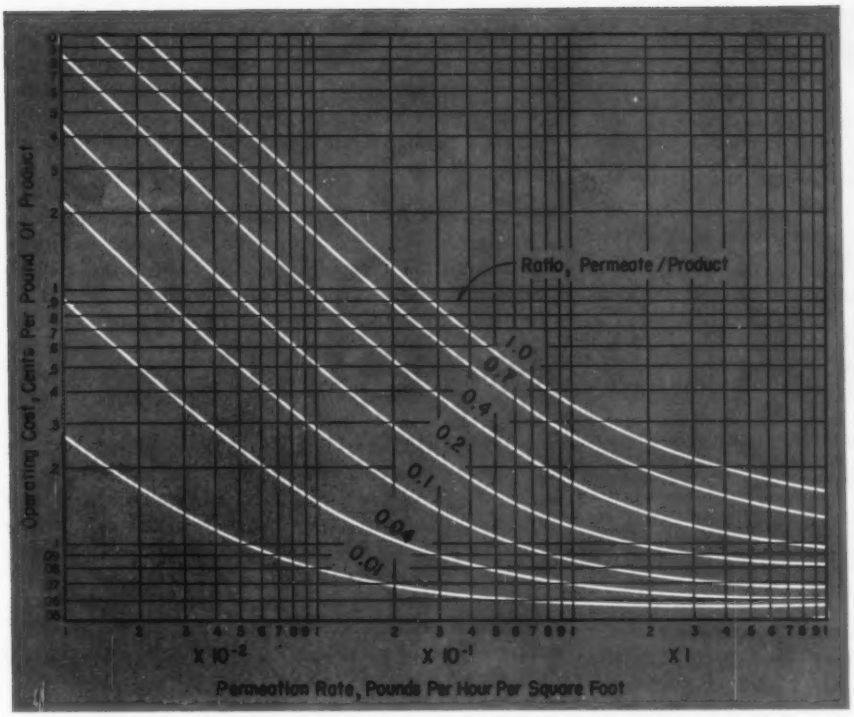

FIGURE 5—Operating cost as a function of permeation rate and permeate/product ratio (Basis: labor rate, $3/hr; laboratory, 50 percent of direct labor; overhead—factory and payroll, 120 percent of direct labor; supervision, $4.50 hr; maintenance rate, $3/hr; steam cost, 75¢/1,000 lbs; and membrane life, 2,000 hours).

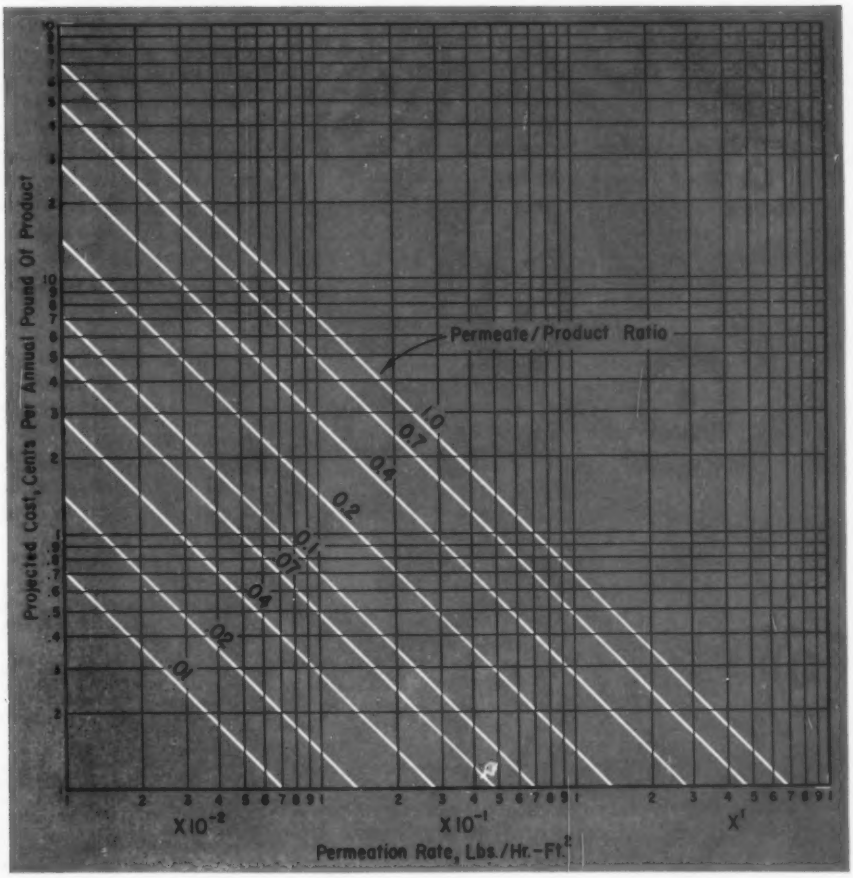

FIGURE 6—Cost of cell installed as function of permeation rate and permeate/product ratio (Base price: $50/square foot).

permeation rate for different ratios of permeate to product. It is seen that in general it is more important from a cost standpoint to improve the separating factor than to strive for an increase in permeation rate, although the latter is also very important.

Capital Investment. It is anticipated that commercial installations will cost between $50 and $100 per square foot of membrane surface, depending among other factors on material of construction and specific design requirements. Figure 6 shows cell investment in terms of cents per annual pound as a function of permeation rate for varying ratios of permeate to product. In this connection, most permeation rates for separations of potential interest have been found to lie between 0.2 and 2.0 pounds per hour per square foot, with permeate/non-permeate ratios being 0.4 or less.

To the capital cost projectable from Figure 6 must be added the cost of auxiliary equipment (preheater, reheaters, condenser, pumps, piping, instrumentation, insulation, installation, etc.). For production rates between one-thousand and ten-thousand pounds per hour, the latter will amount to approximately 0.1 to 0.2 cents per annual pound. Thus, for the cited example where the permeate to product ratio was 0.4 and the permeation rate 0.4 pounds per hour per square foot the installed plant complete with auxiliaries will cost approximately one cent per annual pound.

Factors Affecting Permeation. The efficiency of the permeation process is dependent upon both rate and selectivity, and hence these factors must be considered jointly. Obviously, high rate as well as high selectivity must be achieved if this process is to be considered for commercial application. For any given liquid mixture, it has been found that both of these factors are, to a large extent, dependent on the type of film used. For example, the selectivity of one component over another can be increased by the selection of the proper film. This phenomenon has been observed in the case of a methanol-benzene mixture and presumably holds true for most mixtures of hydrocarbons and oxygenated hydrocarbons; in fact, it may become a common phenomenon as more experience is obtained.

About the Authors

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Dr. Chai Y. Choo is in charge of laboratory research and pilot plant development of membrane permeation at Ionics, Incorporated. He has been active in the membrane permeation field for the past four years. He received the degree of Doctor of Science in Chemical Engineering from Massachusetts Institute of Technology in 1960 and was an assistant professor of chemical engineering at Northeastern University before joining Ionics.

Films used for membrane permeation range in thickness from 3 down to 0.5 mils or less. It is difficult to predict film stability in any way other than by actual experimentation. However, films have been in use under a variety of conditions for several months of continuous operation with no mechanical failure provided abuse such as puncture by sharp or pointed objects is prevented.

For a given film, the attainment of maximum rate and selectivity is dependent on the following variables:

- **Permeation Temperature**—An increase in temperature will yield an increase in permeation rate.[1,2,5] However, sometimes this is accomplished by a more or less marked decrease in selectivity. In an actual separation process, therefore, the optimum permeation temperature should correspond to the highest temeperature compatible with desired selectivity.
- **Film Thickness**—The permeation rate is not a function of film thickness. However, since the permeation rate is defined as rate per unit area and unit film thickness, throughput per unit time and unit area is inversely proportional to film thickness. This has been borne out experimentally.
- **Properties of Permeating Molecules**—Solubility is determined primarily by the difference in the chemical nature of the permeating molecules, while diffusivity is determined largely by the size and shape of these molecules and by the degree of aggregation among the diffusing material within the polymer.

Conclusions. It has been shown that many variables must be optimized in order to increase the efficiency of the membrane permeation process. These include operating conditions and overall process considerations such as the desired end-concentration of the two effluent streams. Already, many separations are commercially feasible so that as additional films become developed, economics of these separations undoubtedly will be improved even further while additional separations will become economically attractive.

Lastly, we have talked about commercial units having 1000 square feet of membrane surface. Eventually, the unit size may increase also; this should favorably affect investment in terms of $/unit area. Regardless of size, at most one-quarter man will be required to tend the instruments that control the operation of the unit. Therefore, one should look forward also to an even lower operating and capital cost than that presently projected.

Thus, while membrane permeation only recently has entered the commercialization phase, it is predicted that the process soon will play an important role in the separation field.

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Latest Advances in Superfractionation

In cases where the relative volatility varies from top to bottom trays, use this new design procedure

Francis W. Winn
Fritz W. Glitsch & Sons, Inc., Dallas

SUPERFRACTIONATORS are getting larger and longer. The maximum number of trays used in one train in 1956 was about 300.[3] Figure 1 shows a xylene-ethylbenzene separation involving 750 trays.[5]

There is no generally recognized definition of a superfractionator. The term originated with the Phillips Petroleum Company to identify separations which required several times the 30 to 40 decks frequently used in refinery separations. A superfractionator is defined here as one involving 30 or more threoretical stages at total reflux. The relative volatility is generally below 1.5 and the purity of one or more products may be better than 99 percent.

Superfractionators are in service for separating ethylene from ethane, propylene from propane, isobutane from n-butane, butylenes and butadiene from butanes, isopentane from n-pentane, ethylbenzene from styrene and xylenes, and o-xylene from meta and para xylene, and many other systems. Superfractionators are frequently used in conjunction with liquid-liquid extraction, extractive distillation, fractional crystallization, and other exchange processes.

A thorough study of investment and operating costs is justified in superfractionator design. Pressure drop, efficiency, capacity and turndown ratio are the three critical performance aspects of tray design. Valve type trays and sieve trays have been used most frequently in recent years. Bubble cap trays and some proprietary trays are also used. Column height or pressure drop limitations may require the use of a train of two or more towers in series. The train diameter may decrease in size as the concentration of products increase. When the feed rate is so high as to require two or more trains in parallel because of tower diameter limitations, it may be economical to combine products

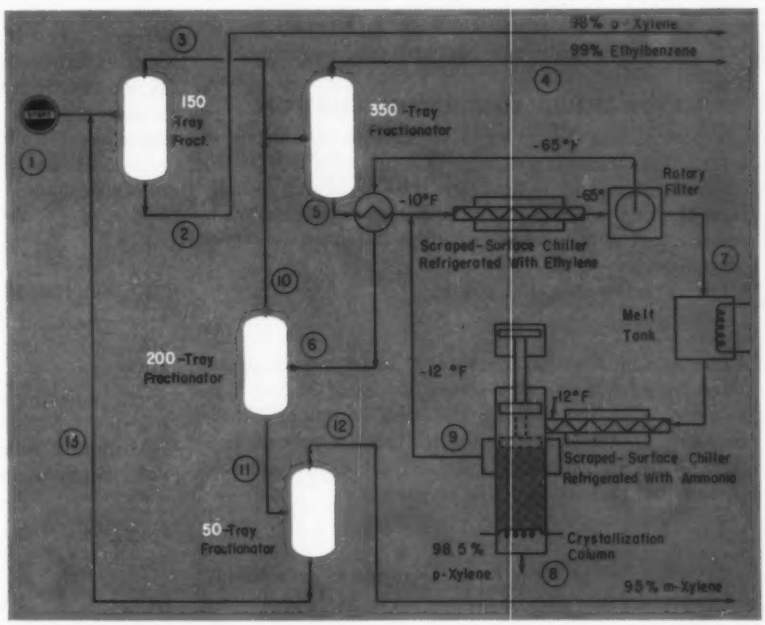
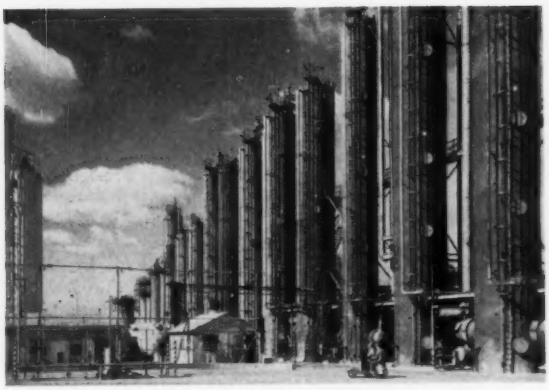


FIGURE 1—Phillips uses 750 trays for this xylene separation process. Superfractionation is combined with crystallization to produce pure isomers.

SEPARATION METHODS

Superfractionation



Superfractionators at Phillips Petroleum Company's Borger plant produce special fractions from natural gas liquids.

These fractionating columns are the heart of the ethylbenzene unit at Cosden Petroleum Corporation, Big Spring.

from intermediate columns in the trains and feed to a common finishing or final concentration tower.

The relative volatility from top to bottom trays in a superfractionator may vary appreciably. For this reason, an average relative volatility cannot always be used with reliability. A difference of 10 to 20 percent from the optimum in reflux or number of trays can involve thousands of dollars in investment and annual operating costs. An exact calculation procedure is needed in order to provide an accurate relation between the number of trays and reflux rate.

The following procedure represents a new approach to solving distillation problems accurately for cases where the relative volatility does vary from top to bottom trays. It is applicable over sections of each column where the L/V ratio is constant. Fortunately, most superfractionators have a constant L/V ratio for all trays in both the rectifying and stripping sections.

VAPOR-LIQUID EQUILIBRIUM RELATION

A plot of log K vs log k at various conditions of composition, temperature and pressure which exist between the top and bottom trays in a column usually gives a straight line.[7] This applies even with a wide pressure and temperature spreads between top and bottom trays.

The equation of such a plot is

$$K = \beta k^{\theta} \tag{1}$$

The constants in this equation, β and θ, can be determined by substituting two sets of values of K and k in Equation (1) and solving the two equations simultaneously. If the bottoms product from a column is a relatively pure component, β is equal to the relative volatility at the bottom of the column,

$$\beta = \alpha_{btm} \tag{2}$$

If the overhead product from a column is a relatively pure component, θ can be calculated from the following equation.

$$\theta = \log(\alpha_{top})/\log \beta \tag{3}$$

The binary equilibrium curve is obtained by substituting $K = y/x$ and $k = (1-y)/(1-x)$ in Equation (1)

$$y/x = \beta[(1-y)/(1-x)]^{\theta} \tag{4}$$

This equation can be solved for the x,y or McCabe-Thiele diagram by trial and error. However, values of x and corresponding values of y can be readily determined by substituting various values of k in the following simultaneous equations:

$$K = \beta k^{\theta} \tag{5}$$

$$x = (1-k)/(K-k) \tag{6}$$

$$y = Kx \tag{7}$$

The slope of the equilibrium curve is useful for calculating the number of stages required at finite reflux. Either of three equations may be used. Equation (8) is most useful when x is small; at x equal to 0, dy/dx equals β. Equation (9) is most useful when x is near unity; at x equal to 1.0, dy/dx equals $(1/\beta)^{\omega}$. Equation (10) is useful at any concentration.

$$\frac{dy}{dx} = \beta\left[\frac{1-x(1-\theta)}{1-y(1-\theta)}\right]\left[\frac{1-y}{1-x}\right]^{1+\theta} \tag{8}$$

$$= \left[\frac{1}{\beta^{\omega}}\right]\left[\frac{1-x(1-\theta)}{1-y(1-\theta)}\right]\left[\frac{y}{x}\right]^{1+\omega} \tag{9}$$

$$= (Kk)\left(\frac{1-x(1-\theta)}{1-y(1-\theta)}\right) \tag{10}$$

where ω is equal to $1/\theta$.

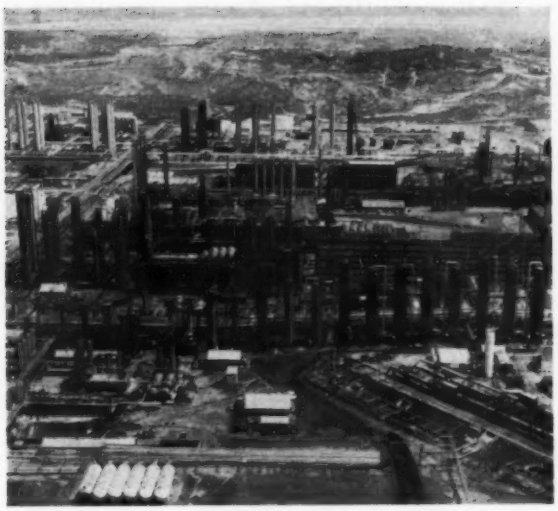
MINIMUM REFLUX

Minimum reflux at infinite stages can be calculated with the following equations for binary systems.

$$(L_m @ q = 1) = \left[\frac{f_{LK} + f_{HK}}{\alpha - 1}\right]\left[\frac{d_{LK}}{f_{LK}} - \frac{\alpha d_{HK}}{f_{HK}}\right] \tag{11}$$

$$(L_m @ q = 0) = \left[\frac{f_{LK} + f_{HK}}{\alpha - 1}\right]\left[\frac{w_{HK}}{f_{HK}} - \frac{\alpha w_{LK}}{f_{LK}}\right] + W \tag{12}$$

$$L_m = q(L_m @ q = 1) + (1-q)\ (L_m @ q = 0) \tag{13}$$



Phillips' fractionators at Borger are part of the world's largest facilities for natural gas liquid.

where q is the thermal condition of the feed. When molal overflow is constant, q is the fraction of the feed not vaporized or the equivalent. The relative volatility to be used in the above equations should be at feed tray conditions.

Equations (11) and (12) are exact for binary systems and with modifications to be published at some future date can be used for multicomponent systems.

THEORETICAL STAGES AT TOTAL REFLUX

The following equation[7] gives the minimum number of theoretical stages required to obtain the desired separation

$$(\beta)^{S_m} = \left[\frac{x_d}{x_w}\right]\left[\frac{1-x_w}{1-x_d}\right]^{\theta} = \left[\frac{x_d}{x_w}\right]_{LK}\left[\frac{x_w}{x_d}\right]^{\theta}_{HK} \qquad (14)$$

where S_m is the minimum number of theoretical stages including the reboiler and partial condenser (if one is used). This equation is exact for binary and multicomponent systems. It applies to every pair of components and may be used to establish the distribution of non-key components at total reflux which closely approximates the distribution at finite reflux. See reference 7 for a full discussion.

THEORETICAL STAGES AT FINITE REFLUX

Figure 2 shows a plot of the equilibrium curve and the two operating lines for a binary system in a manner similar to that used by Stoppel.[4] The two x intersections of the upper operating line with the equilibrium curve are designated x_g and x_j. These two points are used as the origin and unity terminal of a modified x′,y′ coordinate system. Each point on the x,y diagram is related to the x′,y′ diagram as follows:

$$x' = (x - x_g)/(x_j - x_g) \qquad (15)$$

$$y' = (y - y_g)/(y_j - y_g) \qquad (16)$$

The slope of any line on the x,y diagram is related to its slope on the x′,y′ diagram by:

$$dy'/dx' = (dy/dx)/(r) \qquad (17)$$

The equation of the operating line and the equilibrium curve in terms of the x′,y′ system are:

$$y' = x' \qquad (18)$$

$$y'/x' = (\beta')[(1-y')/(1-x')]^{\theta'} \qquad (19)$$

with β' and θ' defined later. An equation can be derived from Equations (18) and (19) to calculate the number of stages above the feed at any finite reflux ratio for any two values of x′ in a manner similar to that used for total reflux.

The two intersections of the lower operating line with the equilibrium curve gives x_a and x_b coordinates which may be used in a similar manner to obtain the number of stages below the feed tray.

If the slopes of the operating line are not constant, the equations can be applied over portions which do have a constant slope.

EXAMPLE CALCULATION

An example calculation illustrating use of the equations for a binary system is shown below. The compositions of the distillate, feed and bottoms product are 0.98, 0.6 and 0.002 mole fraction, of the light key, respectively. The feed flashes to 60.115 percent liquid on entering the column, i.e., q = .60115. Constant molal overflow will be assumed. A reflux rate 1.4 times the minimum will be used. Vapor-liquid equilibrium constants are as follows:

	Top Tray	Feed Tray	Reboiler
K	1.006	1.106	1.2
k	.7028	.85	1.00
α	1.431	1.301	1.2

Use the top and bottom trays to calculate β and θ.

$$1.006 = \beta(.7028)^{\theta}$$
$$1.2 = \beta(1.0)^{\theta}$$
$$\beta = 1.2$$
$$\theta = 0.5$$

The material balance is as follows:

	Mols/hr			Mol Fraction	
	Feed	Ovhd	Btms	Ovhd	Btms
Light Component	60.0	59.922	.078	.98	.002
Heavy Component	40.0	1.223	38.777	.02	.998
	100.0	61.145	38.855	1.00	1.000

Minimum Stages:

$$(1.2)^{S_m} = \left[\frac{.98}{.002}\right]\left[\frac{.998}{.02}\right]^{5}$$

$$S_m = 44.7$$

Minimum Reflux:

$$L_m\ (@\ q=1) = \left[\frac{100}{1.301-1}\right]\left[\frac{59.922}{60} - \frac{(1.301)\ (1.223)}{40}\right] = 318.6$$

$$L_m\ (@\ q=0) = \left[\frac{100}{1.301-1}\right]\left[\frac{38.777}{40} - \frac{(1.301)\ (.078)}{60}\right] + 38.8 = 360.4$$

$$L_m = (318.6)\ (.60115) + (360.4)\ (.39885) = 335.3 \text{ moles/hr.}$$

For comparison, an exact solution gives 335.8 moles/hr.
Using a reflux rate of 1.4 times the minimum gives an L/V

ratio for trays above the feed tray of r = .885. The L/V ratio for trays below the feed tray is R = 1.079.

STAGES VERSUS L/V FOR TRAYS ABOVE FEED TRAY

The following procedure is convenient for calculating the number of stages required for any L/V ratio above the feed tray.

(1) The x_g intersection of the upper operating line with the equilibrium curve is most readily determined as follows:

(A) Assume a value of k_g which is slightly greater than r, where r is the L/V ratio above the feed tray.

(B) Calculate $K = \beta k^{\theta}$

(C) Calculate $x = (1 - k)/(K - k)$

(D) Calculate $y_e = Kx$

(E) Calculate $y_o = (r)\ (x)\ + x_d(1 - r)$

(F) Compare (D) with (E) and repeat the procedure with other values of k until agreement is obtained. A rapid convergence to an exact solution can be obtained by using differences between successive trials, i.e., $\Delta(y_e - y_o)/\Delta k$ is nearly a constant.

The x_j intersection is obtained by use of the same equations given under (1) above except K is slightly less than 1.0, i.e., k_j is slightly less than $(1/\beta)^{\omega}$.

(2) Calculate $(dy/dx)_g$ and $(dy/dx)_j$

$$\left(\frac{dy}{dx}\right)_g = \left(\frac{1 - (x_g)\ (1 - \theta)}{1 - (y_g)\ (1 - \theta)}\right)\left(K_g k_g\right) \qquad (20)$$

$$\left(\frac{dy}{dx}\right)_j = \left(\frac{1 - (x_j)\ (1 - \theta)}{1 - (y_j)\ (1 - \theta)}\right)\left(K_j k_j\right) \qquad (21)$$

(3) Calculate

$$\beta' = (dy/dx)_g/(r) \qquad (22)$$

$$\theta' = \frac{\log \beta'}{\log[(r)/(dy/dx)_j]} \qquad (23)$$

(4) Calculate the optimum feed tray composition

$$x_o = \frac{x_d(1 - r) + x_w(R - 1)}{R - r} \qquad (24)$$

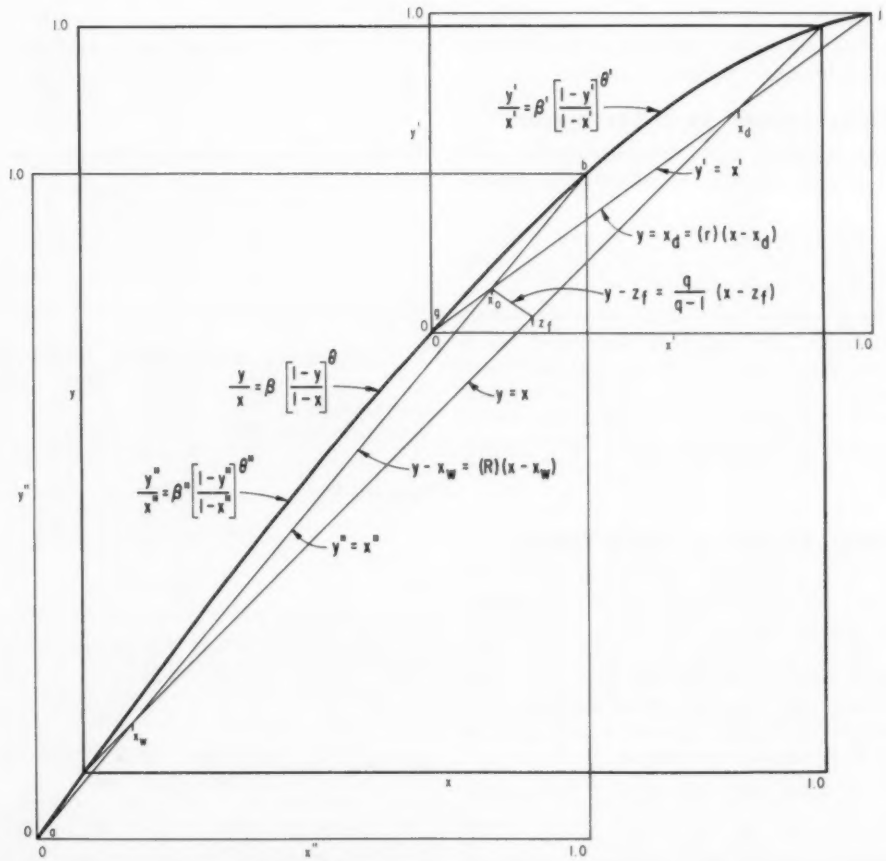


FIGURE 2—A modulated McCabe-Thiele diagram is the basis for calculating theoretical stages at finite reflux.

TABLE 1—Example Calculation of Number of Stages Above Feed Tray

Step (1) Sub-Step	Item	INTERSECTION AT POINT g 1st. Trial	2nd. Trial	3rd. Trial	4th. Trial	INTERSECTION AT POINT j 1st. Trial	2nd. Trial	3rd. Trial	4th. Trial
A	k	.885000	.890000	.889214	.889235	.694444	.690000	.689426	.689441
B	K	1.128890	1.132080	1.131577	1.131591	1.000000	.996795	.996380	.996391
C	1-k	.115000	.110000	.110786	.110765	.306667	.310000	.310574	.310559
	K-k	.243890	.242080	.242363	.242356	.306667	.306795	.306954	.306950
	x	.471524	.454395	.457108	.457034	1.000000	1.010447	1.011793	1.011758
D	y_e	.532299	.514411	.517253	.517176	1.000000	1.007209	1.008130	1.008107
E	y_o	.529999	.514840	.517241	.517175	.997700	1.006946	1.008137	1.008106
F	y_e-y_o	+.002300	−.000429	+.000012	+.000001	+.002300	+.000263	−.000070	+.000001
$\Delta(y_e-y_o)$			+.002729	−.000441			+.002037	−.000270	
Δk			−.005000	+.000786			+.004444	+.000574	
$\Delta y/\Delta k$			−.545800	−.561100			+.458400	+.470400	
3rd. Trial k			.89−(−.000429/−.5458) = .889214				.69−(.000263/.4584) = .689426		
4th. Trial k			.889214−(.000012/−.5611) = .889235				.689426−(.00007/.4704) = .689441		

Step (2) $(dy/dx)_g = \frac{1-(.457034)\ (1-.5)}{1-(.517176)\ (1-.5)}(.889235)\ (1.131591) = 1.0471$

$(dy/dx)_j = \frac{1-(1.011758)\ (1-.5)}{1-(1.008107)\ (1-.5)}(.689441)\ (.996391) = .6844$

Step (3) $\beta' = 1.0471/.885 = 1.1832$

$\theta' = \log 1.1832/\log (.885/.6844) = .6545$

Step (4) $x_o = \frac{(.98)\ (1-.885) + (.002)\ (1.079-1)}{1.079-.885} = .5817$

Step (5) $x_d' = \frac{.98 - .457034}{1.011758-.457034} = .9427$

$x_o' = \frac{.5817-.457034}{1.011758-.457034} = .2247$

Step (6) $1.1832^{S'} = \left[\frac{.9427}{.2247}\right]^{.6545}\left[\frac{.7753}{.0573}\right] = 23.075$

$S' = \log 23.075/\log 1.1832 = 18.66$

The number of stages above the optimum feed tray location is 18.7.

(5) Calculate

$$x_d' = \frac{x_d - x_g}{x_j - x_g} \tag{25}$$

$$x_o' = \frac{x_o - x_g}{x_j - x_g} \tag{26}$$

(6) Calculate the number of stages above the feed tray

$$(\beta')^{S'} = \left[\frac{x_d'}{x_o'}\right]\left[\frac{1-x_o'}{1-x_o'}\right]^{\theta'} \tag{27}$$

See Table 1 for example calculation.

STAGES VERSUS L/V FOR TRAYS BELOW THE FEED TRAY

The following procedure is convenient for calculating the number of stages required for any L/V ratio below the feed tray.

(1) The x_a intersection of the lower operating line with the equilibrium curve can be determined most readily by the following procedure:

(A) Assume a value of k_a which is slightly greater than 1.0

(B) Calculate $K = \beta k^\theta$

(C) Calculate $x = (1-k)/(K-k)$

(D) Calculate $y_e = Kx$

(E) Calculate $y_o = (R)\ (x) - (x_w)\ (R-1)$

(F) Compare (D) with (E) and repeat the procedure with other values of k until a solution is obtained. A rapid convergence to an exact solution can be obtained by using differences between successive trials; i.e., $\Delta(y_e - y_o)/\Delta k$ is nearly a constant.

The x_b intersection is obtained by the same equations given under (1) above except K is slightly less than R, i.e., k is slightly less than $(R/\beta)^\omega$ where R is the L/V ratio below the feed tray.

(2) Calculate the slope of the equilibrium line at x_a and x_c.

$$\left(\frac{dy}{dx}\right)_a = \left(\frac{1-(x_a)\ (1-\theta)}{1-(y_a)\ (1-\theta)}\right)\left(K_a k_a\right) \tag{28}$$

$$\left(\frac{dy}{dx}\right)_b = \left(\frac{1-(x_b)\ (1-\theta)}{1-(y_b)\ (1-\theta)}\right)\left(K_b k_b\right) \tag{29}$$

(3) Calculate

$$\beta'' = (dy/dx)_a/R \tag{30}$$

$$\theta'' = \frac{\log \beta''}{\log R/(dy/dx)_b} \tag{31}$$

(4) Calculate the optimum feed tray composition

$$x_o = \frac{(x_d)\ (1-r) + (x_w)\ (R-1)}{R-r} \tag{32}$$

(5) Calculate

$$x_w'' = \frac{x_w - x_a}{x_b - x_a} \tag{33}$$

$$x_o'' = \frac{x_o - x_a}{x_b - x_a} \tag{34}$$

(6) Calculate the number of stages between the reboiler and the feed tray:

$$(\beta'')^{S''} = \left[\frac{x_a''}{x_w''}\right]\left[\frac{1-x_w''}{1-x_b''}\right]^{\theta''} \tag{35}$$

See Table 2 for example calculation.

NUMBER OF STAGES FOR MISLOCATION OF FEED TRAY

The total number of stages is 58.7 + 18.7 or 77.4 provided the feed tray is in the optimum location. If the feed is introduced either too high or too low in the column, additional stages are necessary. The following equations apply:

TABLE 2—Example Calculation of Number of Stages Below Feed Tray

Step (1) Sub-Step	Item	INTERSECTION AT POINT a 1st. Trial	2nd. Trial	3rd. Trial	4th. Trial	INTERSECTION AT POINT b 1st. Trial	2nd. Trial	3rd. Trial	4th. Trial
A	k	1.000000	1.010000	1.000248	1.000260	.808501	.808000	.808167	.....
B	K	1.200000	1.205985	1.200149	1.200156	1.079000	1.078666	1.078777	.....
C	1-k	0.000000	—.010000	—.000248	—.000260	.191499	.192000	.191833	.....
	K-k	.200000	.195985	.199901	.199896	.270499	.270666	.270610	.....
	x	.000000	—.051024	—.001241	—.001301	.707947	.709361	.708891	.....
D	y_e	.000000	—.060589	—.001489	—.001561	.763875	.765164	.764735	.....
E	y_o	—.000158	—.054367	—.001497	—.001562	.763717	.765243	.764735	.....
F	y_e-y_o	.000158	—.006222	+.000008	+.000001	.000158	—.000079	.000000	.....
$\Delta(y_e-y_o$		+.00638	—.00623			+.000237			
ΔK		—.01	+.009752			+.000501			
$\Delta y/\Delta k$		—.638	—.639			+.473			
3rd. Trial k		1.01—(—.006222/—.638) = 1.000248				.808 — (—.000079/.473) = .808167			
4th. Trial k		1.000248—(.000008/—.639) = 1.00026							

Step (2) $(dy/dx)_a = \frac{1+(.001301)(-.5)}{1+(.001561)(-.5)}(1.00026)(1.200156) = 1.2003$

$(dy/dx)_b = \frac{1-(.708891)(-.5)}{1-(.764735)(-.5)}(.808167)(1.078777) = .9112$

Step (3) $\beta'' = 1.2003/1.079 = 1.1124$

$\theta'' = \log 1.1124/\log(1.079/.9112) = .6302$

Step (4) $x_o = \frac{(.98)(1-.885)+(.002)(1.079-1)}{1.079-.885} = .5817$

Step (5) $x_o'' = \frac{.5817+.001301}{.708891+.001301} = .8209$

$x_w'' = \frac{.002+.001301}{.708891+001301} = .00465$

Step (6) $1.1124^{S''} = \left[\frac{.8209}{.00465}\right]\left[\frac{.99535}{.1791}\right]^{.6302} = 520.3$

$S'' = 58.72$

The number of stages below the optimum feed tray location is 58.7.
The total number of stages required is 58.7 + 18.7 or 77.4.

$$(\beta')^{S'} = \left[\frac{x_d'}{x_n'}\right]\left[\frac{1-x_n'}{1-x_d'}\right]^{\theta'} \quad (36)$$

$$(\beta'')^{S''} = \left[\frac{x_n''}{x_w''}\right]\left[\frac{1-x_w''}{1-x_n''}\right]^{\theta''} \quad (37)$$

where x_n' and x_n'' correspond to the composition, x_n, of the liquid leaving the bottom stage of the upper section. Note x_n cannot be less than x_g nor greater than x_b.

Assume the feed is introduced at a point in the column where the concentration is 0.50 rather than the optimum concentration of 0.58.

For trays above the feed tray

$$x_d' = .9427$$

$$x_n' = \frac{.50-.457}{1.0117-.457} = 0.775$$

$$(1.1832)^{S'} = \left[\frac{.9427}{.0775}\right]\left[\frac{.9225}{.0573}\right]^{.6545}$$

$S' = 25.7$ compared to 18.7 for the proper location

For trays below the feed tray

$$x_w'' = .00465$$

$$x_n'' = \frac{.50+.001301}{.7089+.001301} = .7059$$

$$(1.1124)^{S''} = \left[\frac{.7059}{.00465}\right]\left[\frac{.99535}{.2941}\right]^{.6302}$$

$S'' = 54.4$ compared to 58.7 for the proper location

The total number of trays is 80.1 for the mislocated feed tray compared to 77.4 for the proper location. This shows that if the feed tray is 7 stages too low in the column, an additional 2.7 stages over-all are required to make product quality.

TOWER PERFORMANCE EVALUATION

The average over-all tower efficiency (not tray efficiency) can be determined from performance data by calculating S′ and S″ by the above procedure using a calculated feed tray composition.

This method does not give an indication of actual tray efficiency because of possible mislocation of the feed tray. A somewhat better value is obtained if the feed tray composition is adjusted to give the same ratio of stages above and below the feed tray as there are decks above and below.

An evaluation of actual tray efficiency can be obtained if samples from several trays at intervals through the tower can be obtained.

A plot of $\log x_i'/(1-x_i')^{\theta'}$ for trays above the feed tray versus tray number on an arithmetic scale will give a straight line if the efficiency is constant from tray to tray. If a curved line is obtained, the tower may not have been at equilibrium or the L/V ratio by heat and material may not be correct. If such a plot is a series of broken lines, the efficiency is different for each segment. This method can be used to locate mal-performing trays. The efficiency is calculated from the following equation:

$$(\beta')^{NE_o} = [(x')/(1-x')^{\theta'}]_{top}/[(x')/(1-x')^{\theta'}]_{btm} \quad (38)$$

where N is the total number of decks in the section, E_o is the over-all tray efficiency, and x′ top and bottom refers to the liquid entering and leaving the section of trays under study.

A similar plot may be used for trays below the feed tray, i.e., plot $(x_i''/(1-x_i'')^{\theta''}$ versus tray number on semi-log paper. The efficiency is obtained by an equation analogous to the one shown above.

Gelus, et al,[2] discusses other factors concerning the evaluation of tower performance with respect to the effect of errors which may be significant.

FRACTIONATOR CONTROL

There are two commonly used methods for control of product purity. One method is by product flow control; i.e., one product is placed on flow control with composition reset. The other product is on level control. Reboiler duty is set independently at a heat input sufficient to produce the desired separation, and reset with changes in feed rate. Reflux is on level control or overflow.

The second method involves placing the reboiler duty on composition control and the reflux on flow control or vice versa. Reboiler duty control is preferred because the column responds more quickly. In either case, both products are on level control.

Temperature measurement as an indication of composition in superfractionators is not usually satisfactory. It is non-specific, i.e., a change in temperature with composition may be far less, even overshadowed completely, by a change in pressure. Stated another way, changes in feed rate or column pressure control may cause a corresponding temperature change due to variation in absolute pressure which bears little relation to composition. Wherry and Berger[6] point out that analytical or specific composition control is frequently more economical, despite investment differences. It must be recognized of course that temperature control is suitable where high product purities are not specified.

Several types of instruments are available for composition analysis. The chromatograph is the most versatile. Density, refractive index and other property measurements, although non-specific, may also be used with some separations.

With variable feed rates and variable feed compositions, cascade controls are justified. If the feed rate and composition are relatively constant, hand reset of the major control loop is sometimes adequate.

Wherry and Berger summarize the factors influencing location of the sampling point for control as follows: "The factors favored by sampling at, or very near, the column terminals are (1) freedom from ambiguity in the correlation of sample composition with terminal composition, and (2) improved control loop behavior due to reduction of transport lag (dead time) and of the time behavior. This assumes that the manipulation for control is applied at the same terminal. The factors favored by sampling nearer the feed entry are (1) improved terminal composition behavior due to earlier recognition of composition transients as they proceed from the feed entry toward the column terminals, and (2) less stringent analytical requirements due to (a) analyzing the control component at a higher concentration and over a wider range, (b) simplifying the multicomponent mixture since non-key components tend to exhibit constant composition zones in the column. These latter points often make 'impossible' analyses possible." Uitti[8] and Fenske and Broughton[1] give a thorough treatment on the effect of control point location on column control.

About the Author

Francis W. Winn is director, research development, for Fritz W. Glitsch and Sons, Inc. A chemical engineering graduate of the University of Oklahoma, he was formerly technical director for Fractionation Research, Inc. He has been associated with a number of major oil companies and was assistant chief process engineer with Catalytic Construction Company.

Instruments and control computers which apply the correct signal at the instant required will permit high product purities or higher feed rates than that possible by ordinary control methods.

NOMENCLATURE

- α — relative volatility — K/k
- β — constant in Equation (1) and related equations
- θ — exponent in Equation (1) and related equations
- ω — reciprocal of θ
- d — component in distillate, moles/unit time
- D — total distillate, moles/unit time
- E_o — over-all deck efficiency
- f — component in feed, moles/unit time
- K — vapor-liquid distribution coefficient of light component
- k — vapor-liquid distribution coefficient of heavy component
- L — liquid rate, moles/unit time
- L_m — minimum reflux rate above feed tray, moles/unit time
- N — total number of decks in a section
- q — thermal condition of feed
- S — number of stages
- V — vapor rate, moles/unit time
- w — component in bottoms product, moles/unit time
- W — total bottoms product, moles/unit time
- x — mole fraction of light component in liquid
- x_o — optimum feed tray composition, mole fraction
- y — mole fraction of light component in vapor
- y_e — equilibrium value of y
- y_o — operating line value of y
- z — mole fraction of a component in feed
- dy/dx — slope of equilibrium curve

Subscripts:

- a, b — lower and upper intersection of stripper operating line with equilibrium curve
- g, j — lower and upper intersection or rectifier operating line with equilibrium curve
- i — individual tray
- d — distillate product
- f — feed
- HK — heavy key component
- LK — light key component
- m — minimum
- n — tray n below top tray
- w — bottoms product

Superscripts:

- $'$ — (prime) for trays above feed tray
- $''$ — (double prime) for trays below feed tray

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Latest Advances in Extractive Distillation

Most of the recent developments in extractive distillation concern the choice of proper separating agent. Review these present uses

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SOMETIMES, MATERIALS having about the same volatility can be separated from each other by distillation if an "agent" or "solvent" is added. The agent is effective because its presence increases the liquid-phase non-ideality of one component more than the other. Thus choice of a suitable agent requires knowledge of the principles of non-ideal solution behavior.

Most of the recent developments in extractive distillation are concerned with the choice of proper separating agents, rather than improving procedures for column design and operation. The economics of any proposed process is heavily dependent upon the performance of the agent.

Once a desirable agent is found and equilibrium relationships are established, the column is designed and operated in nearly the same manner as an ordinary multicomponent column with two feed streams. The first feed stream consists of the materials to be separated, while the second feed stream is the agent, usually added near the top so that it will be present on most of the trays of the column.[22]

Application of extractive distillaton is made in situations where the increased relative volatility more than compensates for the added costs incurred by purchasing the solvent and providing for its recycle through the column.

The number of process applications in active use today is not very much greater than at the time extractive distillation was first widely used a little over 15 years ago. The use of extractive distillation as a method for separating butanes from butylenes and butylenes from butadiene remains as important today as it was during World War II. The two extractive distillation processes widely used at that time were the Phillips furfural-water process,[6, 23] and the Shell acetone-water process. Both remain in active use today, and the former was chosen by the Texas Butadiene and Chemical Company when it decided in 1955 to build a new plant for the yearly production of 64,800 tons of butadiene and 2½ million barrels of high-octane aviation-grade gasoline.[4]

Shell has found it profitable to use acetonitrile in place of acetone as the extractive solvent for *n*-butane—1-butene separations in its Torrance, Calif., butadiene plant,[9] although much interest remains in the use of acetone as a selective solvent for this separation.[12] A few vapor-liquid equilibrium data for the *n*-butane—1-butene—acetonitrile system are given in the literature.[3]

Most of the extractive processes for paraffin-olefin separations are also suitable for separation of aromatics from paraffins or naphthenes.[24] However, the Udex extraction process is extremely competitive in this application[17] as is the Shell sulfolane process.[11]

The use of water as an extractive distillation solvent has proven to be highly effective for many organic chemical separations. Carlson, Smith, and Morrell showed[7] that the products from a Fischer-Tropsch synthesis plant could be separated by this procedure. They found complete separations according to class could be made in one operation: for example, alcohols from methanol through l-pentanol could be separated as a class from ketones, aldehydes, esters, etc.

Separations within a class can also be accomplished under water extractive distillation conditions: for example, isopropyl alcohol can be easily separated from ethanol. These authors have indicated that materials of about the same boiling point have their relative volatilities increased in the following order in the presence of 90 mole percent water in the liquid phase:

- Organic acids (least volatile)
- Normal alcohols
- Branched primary alcohols
- Secondary alcohols
- Tertiary alcohols
- Ketones
- Aldehydes (except formaldehyde)
- Ethers
- Hydrocarbons (most volatile)

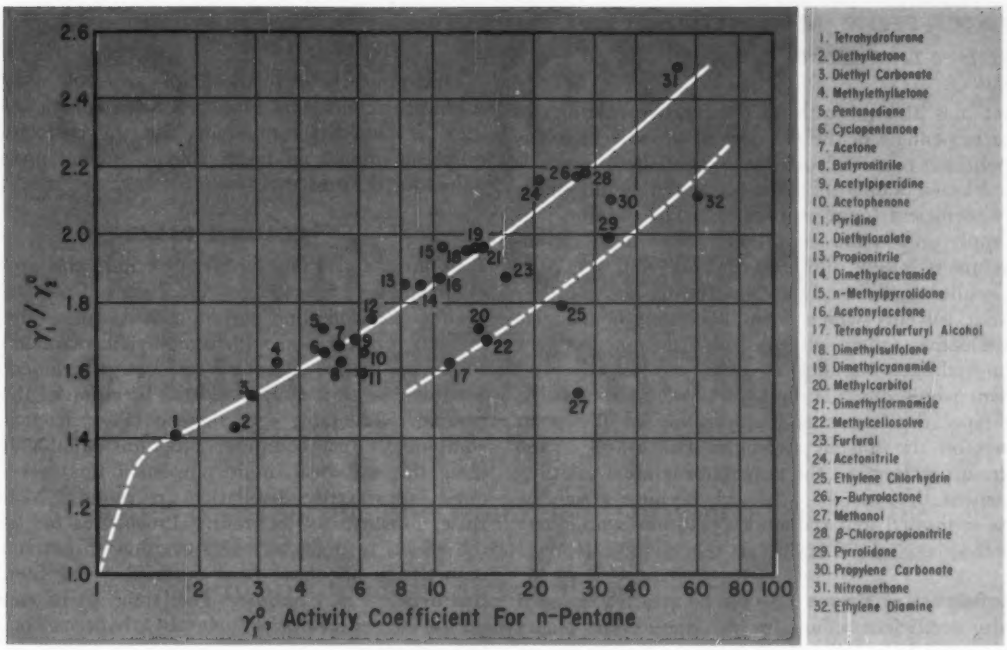

FIGURE 1—Ratio of activity coefficients for n-pentene and 1-pentene as a function of n-pentane activity coefficient for 25° C. and infinite dilution of C_5 components (See Reference 13). Numbers refer to solvents with which C_5 components are mixed; solid points are hydrogen-bonding solvents.

Water extractive distillation has also proven helpful in separating the various products derived from the partial oxidation of hydrocarbons. Hopkins and Fritsch[19] describe separations of this type used in the Bishop, Texas, plant of Celanese; separations are made between methanol and the acetal of formaldehyde and methanol, between n-propanol and allyl alcohol, and between acetals and methylethylketone.

CHOICE OF AGENT

If extractive distillation is to be applied to a given separation, consideration must first be given to choice of the proper separating agent. The economics of any proposed process is heavily dependent upon the performance of the agent. Most of the recent developments in extractive distillation have been along these lines, rather than along lines of improving procedures for column design and operation.

Choosing an extractive distillation agent would be simple if vapor-liquid equilibrium relationships for non-ideal multicomponent mixtures could be readily predicted. However, choice of suitable agents for most commercial processes have been made by trial. The work of Hess, Naragon, and Coghlan[18] is typical of this approach; solvents of nearly every chemical type were evaluated to find the best one for a *n*-butane—2-butene separation. This approach is time-consuming, not only because so many solvents must be tested, but because the relative volatility is affected by temperature, solvent concentration, and relative amount of the feed components present in the liquid. Chu and associates[10] also used the trial-and-error method to find a suitable extractive distillation agent for separating m- and p-xylenes; none of the 39 solvents tested were found to be feasible.

Gas chromatography apparatus might profitably be used to test a large number of extractive solvents. Warren, Warren and Yarborough[31] used a gas chromatograph to determine the partition coefficient ratios of various solute pairs in the presence of various solvents. They then determined the relative volatility of the same solute-solvent mixtures in an equilibrium still. In general, the agreement was good between the partition ratios and the relative volatilities. The use of gas chromatography to measure the vapor-liquid behavior of non-ideal mixtures has also been used to advantage by Porter and associates.[26,27]

Published information on solvent selectivity in absorption or extraction applications also can be used to predict behavior of the same solvents for the separation of the same classes of feed components by extractive distillation.[8] Information contained in the two extraction articles mentioned before[11,17] is most suitable, as is the information compiled by Schutt[30] on solvents for the selective absorption of acetylene from ethylene. The latter information would be useful in considering an extractive distillation process for separating these substances or their higher-boiling homologs.

A recent report by Gerster, Gorton, and Eklund[13] shows the results on a study of the factors affecting the selectivity and capacity of various solvents for the separation of *n*-pentane from 1-pentene by extractive distillation. These authors were able to show that the selectivity of a given solvent increases as the degree of liquid-phase non-ideality of either C_5-solvent binary pair increased. The correlation they prepared is repeated in Figure 1.

The function plotted along the ordinate, $\gamma_1^\circ/\gamma_2^\circ$, is the activity coefficient for pentane divided by that for

pentene; it is also the ratio of the relative volatility of pentane to pentene in the presence of the solvent to the corresponding relative volatility when the solvent is absent. Plotted along the abscissa is the liquid phase activity coefficient for n-pentane, γ_1°. The data on Figure 1 apply only under conditions where the C_5 components are infinitely dilute, and at 25° C.

The results of this study are interesting because they show that solvents which form hydrogen bonds give poorer selectivity than solvents which do not; and, for the non-hydrogen-bonding solvents, the selectivity is dependent wholly upon the magnitude of γ_1° regardless of the type, number, and configuration of the polar groupings on the solvent molecule. The graph is also valuable in pointing out the maximum relative volatility improvement that can be achieved, because miscibility becomes so limited that economic operation is no longer possible if γ_1° exceeds 20 or 30.

The usefulness of Figure 1 would be greatly expanded if activity coefficient values for pentane-solvent binary mixtures could be predicted. Progress in the prediction of activity coefficients for non-ideal binary mixtures has been demonstrated by the work of Pierotti, Deal, and Derr.[25] These authors have correlated values of γ_1° for methylene homologs R_1X_1 at infinite dilution in methylene homologs R_2X_2 by the equation

$$\log \gamma_1^\circ = A_{12} + B_2 n_1/n_2 + C_1/n_1 + D\,(n_1 - n_2)^2 + F_2/n_2$$

where n_1 and n_2 are the numbers of carbon atoms in R_1 and R_2, respectively, A_{12} is a coefficient depending upon the nature of the functional groups X_1 and X_2, B_2 is a coefficient depending upon the nature of X_2, D is a coefficient depending upon interactions between the R groupings, and F_2 depends upon X_2.

The advantage of this type of correlation lies in the fact that many of the coefficients can be obtained from experimental data available from several types of systems, and then used to predict the behavior in another. The systems for which correlation equations are available are as follows:

- Nearly all types of organics as solutes in water
- Water as a solute in alcohols and ketones
- Alcohols and ketones in paraffins; ketones, aldehydes, esters, and acetals in n-alcohols
- Paraffins in ketones.

About the Author

Dr. J. A. Gerster is professor of chemical engineering at University of Delaware. Having received a Ph.D. degree in chemical engineering at Ohio State University in 1943, Dr. Gerster started teaching and directing research at the University of Delaware in 1946. Some of his research projects include extractive distillation of butadiene for the Office of Rubber Reserve, a tray efficiency project for AIChE, and a plutonium project at Hanford. He is currently working on transient response studies of pilot-plant distillation columns.

Obviously these relationships are not suitable for substances containing more than one functional group, such as dimethyl formamide, but the correlations are quite remarkable in being able to predict quantitative values for the substances covered.

COLUMN DESIGN

O'Brien and Franks have described the application of an analog computer for the design of a column separating acetylene and carbon dioxide from ethylene by extractive distillation with dimethyl formamide.[21] They found the analog computer could be programed rapidly for this type of problem, and the precision of the results compared favorably with those obtained from a digital computer. Other computer programs suitable for handling the non-ideal, multicomponent mixtures encountered in extractive distillation are those of Mills[20] and Rose, Sweeny, and Schrodt.[28] Procedures for including the effects of unequal molal overflow in extractive column design also have been outlined in the literature;[16] this article[16] and another[1] give some plant experience on the tray efficiency of furfural-C_4 hydrocarbon extractive columns.

Prediction of tray efficiency for extractive columns is made easier by publication of the results of the five-year AIChE study of tray efficiencies;[5,14,29] one of these publications contains a revised calculation for the prediction of tray efficiency for a 13-foot and a 13-inch diameter furfural extractive column.[15] The control of a large furfural extractive column by a continuous infrared analyzer has also been described.[2]

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Latest Advances in Liquid Extraction

After considering the volume of products requiring treatment by extractive techniques, these authors forecast the future for liquid extraction

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CONSIDERING THE VOLUME of products which now use liquid extraction, both the raffinate and extract portions from extraction processes are expected to yield many new and improved products in the future.

The article will bring up to date the current status of this useful separation technique.

The material is presented in the following sections:

- Petrochemicals
- Naphthas
- Distillate fuels
- Catalytic feed stocks
- Lubricating oils
- Extraction equipment
- The future

PETROCHEMICALS

In 1958, 21 billion pounds of petroleum hydrocarbons were converted to chemicals.[1] Some estimates are as high as 43 billion pounds, with projections of 100 billion pounds by 1975. In many of the steps of isolating or converting petroleum hydrocarbons into chemicals, extraction in some form is used.

Aromatics and BTX. BTX is used here to denote benzene, toluene and xylenes isolated from petroleum, or refinery streams, by extraction. Table 1 shows the amounts produced in 1958 from petroleum by extraction. Those made from other sources, such as coal tar, are not included.

TABLE 1—BTX Production, 1958

Compound	Millions of Lbs.
Benzene	1000
Toluene	1500
Xylenes	1400
Distillates and solvents	1300

Besides these, higher aromatics—such as those containing 10 carbon atoms (durene), naphthalene and methyl naphthalenes—are isolated. The volume of these materials made is increasing.

These aromatics are extracted from hydrocarbon streams by diethylene glycol or sulfur dioxide. These solvents and some processing details are discussed under "Distillate Fuels." Distillation is used to produce the particular aromatic of the required purity, except in the case of durene and naphthalene where crystallization is better.

Olefins and Diolefins. These are important petrochemicals for they are the starting points for many new products. Many of these are separated by liquid extraction, but there have been no major changes in the extraction process or the equipment.

Table 2 gives the 1958 production of several of these products.[1]

TABLE 2—Olefin and Diolefin Production, 1958

Compound	Millions of Lbs.
Butadiene	1500
Isobutylene	300
Isoprene	10
Diisobutylene	100
Tetrapropylene	400
Tripropylene	65

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Butadiene and Isoprene largely go into synthetic rubber, which is now 66 percent of the U.S. consumption of 1.8 million tons of rubber (synthetic plus natural) per year. The two common solvents used to extract these hydrocarbons are: (a) aqueous solution of copper ammonium acetate and (b) furfural. In the case of the copper acetate solution, the extraction is carried out at 0° to 20° F in a continuous mixer-settler type of extractor having from 5 to 12 contacting stages. For furfural extraction, countercurrent towers are used.

Isobutylene has many chemical uses as well as being the basis for Butyl rubber and other polymers. Diisobutylene is readily made by a simple polymerization of isobutylene with an acid catalyst. The solvent for extracting isobutylene is commonly 65 percent sulfuric acid, the process being carried out in a countercurrent, tower extractor. Isobutylene is removed from other 4-carbon atom hydrocarbons by either a gas-liquid or liquid-liquid extraction.

Tri- and tetrapropylene are made by an acid polymerization of propylene, which is usually extracted from refinery gases by an aqueous solution of sulfuric acid. These are principally used to alkylate benzene (also made by extraction of naphtha fractions) and the resulting compounds, in turn, are sulfonated to make one of the good, low-cost, popular, synthetic soaps, or detergents. These detergents are now a 3.2 billion pound per year product in the United States, as contrasted with conventional soap (sodium salts of palmitic and stearic acids) which is only a 1.1 billion-pound per year product.

Other Petrochemicals. **Cyclohexane** is not currently procured by extracting it from refinery streams; however, large amounts are made by hydrogenating benzene, which is obtained by liquid extraction of these refinery streams. It is estimated about 200 million pounds per year of cyclohexane are made, the bulk of this going into nylon. The organic fibre business in the United States now comprises about 6 billion pounds per year. Of this, 65% is in cotton; 6%, in wool; 20%, in cellulosics (cellophane, etc.); and 9%, in fibres made from petroleum, such as nylon, Orlon, Dacron, Acrylon, etc.

Naphthenic acids are made by extracting petroleum fractions having a boiling range of about 450° to 850° F, with aqueous solutions of caustic or ammonia. The naphthenic acids are regenerated from their salts by sulfuric acid. These acids are then converted into the lead, cobalt, calcium, zinc and iron salts. The total production in 1958 of these naphthenic acid salts was 16 million pounds.[1] These salts are used principally as oxidation catalysts in liquid-phase oxidations (drying oils), and as lube oil additives for imparting detergency and anti-rust properties.

Oil-soluble sulfonates are made by the liquid extraction of the sodium sulfonate from oil, using 50-60% isopropyl alcohol in water. An oil, usually in the lube oil range, is first sulfonated by reacting with strong or fuming sulfuric acid. Sulfonates up to about a 12% concentration are made in the oil. These sulfonates are neutralized and then extracted with the alcohol-water mixture. The extraction is easy, it frequently being possible to reduce the 12% sulfonate in the oil to about 0.1% in a single stage extraction with the alcohol-water solvent in a batch or continuous operation. There have been no new developments in this technique, but it would appear that a better understanding of the extraction process would lead to economies in the solvent treat together with a product of increased quality.

These sulfonates are principally used in the form of their calcium and barium salts as detergents in lube oils to impart good engine cleanliness. The production of these salts of sulfonic acids is now about 400 million pounds per year.[1] The other products that can be made by this process of extensively acid treating selected lube oil stocks are white oils. More than 100 million gallons per year of these are made.

Flexible packing and wrappings are a big item in our economy. In the United States, production of cellophane wrappings amounts to about 450 million pounds per year; and plastic films, to about 250 million pounds per year. These plastic films are mainly derived from petrochemicals which, in many cases, have been separated from petroleum fractions by extraction. It is estimated that by 1975 the manufacture of cellophane and plastic films may each approach 700 million pounds per year.

Synthetic rubbers use many oils prepared by solvent extraction. Depending on the end use of the rubber and the method of processing the polymer made for a specific market, from 5 to 50% of distillate oils is mixed with the polymer. For some uses highly aromatic oils are desired; for other applications paraffinic oils are preferred. These oils are usually made by solvent extraction using sulfur dioxide, phenol, or furfural. Over 60 million gallons per year of these "extender" oils are used. Their viscosities are usually in the range of 6 to 20 centistokes at 210° F. Close cooperation with rubber manufacturers and processors is needed to develop the optimum viscosity, color, aromaticity, solvency, and volatility for these oils.

NAPHTHAS

The extraction of catalytic naphthas and catalytic reformates produces high-octane extracts for premium gasolines or blending agents. By using such extractions, the severity of the cracking or reforming operation can be made independent of octane quality, without the attendant losses in yield that would result if octane quality were dependent only on the conversion process. It is logical to augment the conversion process with a separation process.

The raffinates from such naphtha extractions could be used for lower octane fuels and, in the case of making jet or light diesel fuels, they would be upgraded in quality. Jet fuel volume in the United States is expected to increase from 250,000 barrels per day in 1958 to 390,000 barrels per day in 1963. The use of light diesel fuels is also steadily increasing, especially in highway transportation.

World-wide catalytic reforming capacity is now about 2 million barrels per day, while catalytic cracking capacity is about 6 million barrels per day based on

feed. Accordingly, a versatile, flexible, and cheap solvent extraction process for using any type of naphtha should be an important adjunct to a modern refinery, from the standpoint of fuels (gasoline, kerosine, jet, and diesel) as well as petrochemicals and solvents.

Diethylene glycol (DEG), or mixed glycol, is used for the extraction of catalytic reformates for octane improvement.[2,3,4,5,6,7] Heavy naphthas are not favorable feed stocks because of the boiling point of DEG (473° F) and the need to limit stripper-reboiler temperatures to 375° to 400° F to minimize thermal decomposition. Also, it is desirable to have feed stocks free or low in olefins because of gum formation. Air should be excluded to avoid the production of acids that catalyze polymerization to higher glycols. Naphtha extractions are carried out in the range of about 300° to 375° F and pressures of 100 to 200 psig. Solvent treats are relatively high, i.e., 5-10 to 1 and more (as solvent-to-feed weight ratios) due to the low solubilities used.

Sulfur dioxide can also be used to extract catalytic reformates and virgin naphthas to separate or concentrate the aromatics. Because of the low normal boiling point of sulfur dioxide (14° F), the boiling range of the naphtha is not a limiting item. The stocks must be free or low in olefins because chemical reaction is possible with olefins. The sulfur dioxide recovery is by distillation but, because it can react with hydrocarbons at high temperature, the recovery system must be limited to about 300°-350° F. Accordingly, a substantial portion of the sulfur dioxide is recovered at reduced pressures of about 200 mm. mercury. Compressors are used to raise the sulfur dioxide pressure so it can be condensed with coolants ordinarily available, i.e., water or air. The final cleanup of the raffinate and extract portions is usually by a caustic wash.

In the case of naphthas or reformates, the extraction temperatures are in the range of —20° to —40° F. Because the equilibrium or phase diagram for sulfur dioxide-aromatics-nonaromatics is a closed type at these temperatures, pure aromatics cannot be made with liquid sulfur dioxide in a single extractor. A wash oil is used to extract the nonaromatics from the sulfur dioxide solution, thereby enabling pure aromatics to be made.[8,9]

In using sulfur dioxide as an extractant, the feed stocks must be free of water and careful attention must be paid to keep air out of the system. Otherwise, corrosion of the equipment will result.

Sulfolane, a cyclic 4-carbon atom sulfone, has also been proposed for extracting catalytic reformates.[2] Its normal boiling point is 549° F. With aromatics it exhibits a closed-type of extraction diagram so, to produce aromatics in high concentrations or purities, it is necessary to use a wash oil or a double-solvent-type of extraction procedure. To minimize thermal decomposition of the solvent it is desirable to limit stripper-reboiler temperatures to 375°-400° F. Final solvent cleanup is by steam stripping.

Liquid ammonia, with monomethylamine as a prosolvent and water as an anti-solvent, has been reported in a comprehensive study for extracting hydrocarbon mixtures ranging from the C_6 hydrocarbons through lube oils.[10] The feed stocks included the preparation of pure benzene from a light catalytic naphtha, the extraction of hydroformates, thermally and catalytically cracked naphthas, kerosines, catalytic cycle stocks, and coastal and paraffinic lube oils. In the case of a 200 to 400° F. hydroformate of 81.5 clear Research octane number, there was obtained a 45 volume percent yield of extract of 104 clear Research octane number and a corresponding raffinate of 25 clear Research octane number using weight ratios of solvent to feed of 3-5 to 1. In the case of a 266° to 437° F catalytic naphtha of 89.2 clear Research octane number, there was obtained a 71 volume percent yield of extract of 100.8 clear Research octane number and a corresponding raffinate of 31 clear Research octane number at a solvent treat of 4.5 to 1. A thermally reformed naphtha of 100° to 400° F boiling range, and 71 clear Research octane number, was separated into a 50 volume percent yield of extract of 97 clear Research octane number and a corresponding raffinate of 46 octane number. A narrow-cut catalytic naphtha fraction of 374° to 400° F boiling range containing durene (1,2,4,5-tetramethylbenzene) and other C_{10} aromatics, was also separated into an extract essentially all aromatics, from which durene could be obtained by crystallization. For extracting naphthas (catalytic, thermal, or hydroformed), the total cost for a 5,000-bpd plant is about 1.5 to 2 cents per gallon of extract when 50% of the feed is taken as extract.

It is not necessary to use a wash solvent with ammonia solvents. Open-type triangular diagrams are obtained by using water as an antisolvent. Therefore, extracts in high purity and high yield can be made in a single extraction operation conducted at essentially ambient temperature.

A variety of other solvents have been proposed,[11,12] but present-day practice is based almost entirely on sulfur dioxide, furfural, phenol, and diethylene glycol.

DISTILLATE FUELS

Under this heading are grouped kerosine, gas oil or heating oil, diesel fuel, and jet fuel. The boiling range of these stocks is usually from about 350° to 500° or 700° F. Extraction is used primarily to reduce their aromatic and sulfur content, for the quality of these fuels is affected adversely if the aromatic and sulfur concentrations are high.

The volumes of these fuels consumed is large and there is always the pressure to increase quality because the machines or burners using them are becoming more complex and exacting. Aromatics in kerosine produce sooty flames and carbonaceous deposits in burners; in heating oil they burn more slowly, usually with poorer combustion efficiency, unless specially designed burners are used; in diesel fuels they degrade the cetane index and produce engine roughness and smoke; in jet fuels they cause high luminosity flames and nozzle and burner deposits. It is estimated that the world-wide jet fuel demand by 1965 may be over 700,000 bpd with the U.S. demand about 500,000 bpd.

Other products in this boiling range, also requiring low aromatic content, are spray oils. The market for these oils is now several hundred thousand barrels per year and is steadily increasing. These spray oils are used to combat fungus diseases on banana plants, and

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many orchard products. Their aromatic content is usually judged by unsulfonatable content.

Sulfur dioxide is frequently used on these stocks at extraction temperatures of about —20° to +50° F. Solvent treats are only about 1 to 1 because it usually is not necessary to eliminate aromatics completely. As mentioned elsewhere in this review, the extraction phase relationships are such that a closed extraction diagram exists. This means that pure aromatics cannot be produced with a simple extraction. Currently, this is not of great concern because it is the raffinate, or insoluble portion, that is the desired product of improved quality.

Furfural can be used to remove aromatics from distillates with an initial boiling point of about 500° F and higher.[13] This is because furfural boils at 323° F. The solvent recovery system gets complicated when the feed and furfural boil close together. Distillation is used to recover the furfural. Because of temperature instability, bulk furfural streams should not be heated much above 450° F to avoid pyrolysis. Air must be excluded because furfural oxidizes easily so that gums, polymers, and coke form.

As with sulfur dioxide, pure aromatics cannot be made except with a wash oil system. Here again it is usually the raffinate, or portion of lower aromatic content, that is desired. Nevertheless, attention should be focused on producing high-aromatic-content extracts for, on the one hand, good raffinate in the extract stream is a loss in ultimate raffinate yield (requiring more feed to be processed). On the other hand, a highly aromatic extract should find more new uses than an extract that is merely enriched in aromatics. The trend in marketing products always is to have a product well defined in terms of a specific hydrocarbon type or class.

CATALYTIC FEED STOCKS

When catalytic feed stocks contain excessive amounts of highly nucleated aromatics and objectional metals, it is frequently profitable to extract these to reduce the aromatics and metals. These stocks may be virgin or catalytic cycle oils.

Solvents used are phenol, furfural, and propane in some cases.[14,15,16,17,18] There are no particularly unusual features in the extraction. However, none of these solvents can alone produce extracts very high in, or containing essentially pure aromatics. These highly nucleated aromatics have specific gravities of 1.0 or more and there are apt to be settling problems with phenol and furfural. Sulfur dioxide is also applicable with olefin-free feeds. Ammonia solvents are very selective, and by the use of water as an antisolvent, pure extracts can be made in a single solvent system.[10]

The raffinates, which frequently are waxy in the case of wideboiling stocks, can be converted to lube oils, even in the case of raffinates from cycle stock extraction. The main use is an upgraded feed for the catalytic cracking units, resulting in less gas and carbon formation, better product distribution, and less catalyst contamination and deterioration.

The extracts, when high in aromatics, are used for making carbon black, and high-luminosity, high-radiation fuels for open hearth furnaces. They are also useful in making carbon electrodes and binders for electrochemical processes.

Methylated naphthalenes that occur in good yields in catalytic cycle oils, can either be isolated as new petrochemicals by extraction and distillation, or demethylated by hydrogen under pressure in the presence of catalysts to make naphthalene, the demand for which is steadily increasing.

The polycyclic or highly nucleated aromatics in catalytic cycle oil extracts can be hydrogenated to make the corresponding fully hydrogenated, condensed naphthenes, such as the alkylated decalins. These materials appear to be good fuels for high performance jet engines, for they optimize heat of combustion in terms of Btu per gallon and per pound. These fully hydrogenated, condensed naphthenes also show promise as rocket and missile fuels.

The condensed, highly-nucleated aromatics made by extracting cycle stocks, when further refined to eliminate trace elements and unstable hydrocarbons, have very good thermal stability and resistance to nuclear radiation. Accordingly, they are being studied as reactor coolants for atomic power generating stations. These extracts are liquids and, by distillation, any boiling point range can be made. They have the advantage over steam as a reactor coolant in that high pressures in the atomic reactor could be avoided, and also they would be inert to many nuclear fuels, should leaks occur. In contrast to specific organic moderators, these refined extracts have the advantage of being plentiful and cheap. Such extracts could also serve as lubricants for machinery subjected to nuclear radiation.[19]

LUBRICATING OILS

Although the solvent refining of lubricating oils on a commercial scale is now nearly 30 years old in the United States, there have been no new, broad advances. Attention has been given to improved extractor design, partly because there was considerable room for improvement, and partly because this was a way to cut extraction costs. Nevertheless, the solvent refining of lube oils is still more of an art than a science. As long as this situation exists, someone certainly can make a breakthrough that will have a marked effect on lubricating oil quality, applications, and understanding. Much of today's manufacture of lube oils is based on doing what comes easily and naturally by means of solvent extraction, and then finding an additive package to meet the quality requirements, as they arise, largely by trial and error methods.

In extracting complex lube oil stocks, no one solvent gives exactly the same yield, viscosity index, viscosity, carbon residue, volatility, and additive response as another solvent. This is because solvents behave differently with respect to what they choose to dissolve. There is no basic understanding of the solubility relationships when processing complex hydrocarbon mixtures ranging in molecular weight from 350 to 1000 and above, and in molecular types from highly nucleated aromatics to simply branched paraffins. It is remarkable, in view of this complex mass of ignorance, that the petroleum

industry has done a very commendable and outstanding job of lubricating the complex machinery that characterizes today's era of wheels and wings.

There is considerable activity in finding new lubricants for new applications, and many of these require special and high quality products. Automatic transmission fluids (ATF) now comprise about 15 percent of the motor oil volume, and from 50 to 100 million gallons are made per year. These oils must have high viscosity index with low pour points, good low-temperature-flow properties and good lubricity, and must be clean with a high stability toward oxidative and thermal breakdown. Solvent refining is a necessary process for meeting all the quality requirements.

The automotive industry is developing the transaxle unit where the transmission and axle machinery are combined in a single unit. It is difficult to find the lubricant that can meet all the lubrication demands of this unit. Solvent refined oils will certainly be a starting point.

Lube Oil Extraction. Table 3 lists the current status of extraction solvents and capacities.[20]

TABLE 3—Lube Oil Solvent Extraction Capacity, 1959

Solvent	B/D
Phenol and Duo-Sol	127,250
Furfural	69,500
Chlorex	7,000
Nitrobenzene	2,800
	206,550

The Duo-Sol process, used primarily to make bright stocks, employs cresols and propane as extraction solvents. As noted in Table 3 phenol and furfural are the principal extractants. There have been no new solvent developments on a commercial scale, nor any basic changes in the plant operation.

Deasphalting. Solvent deasphalting capacity using propane, together with small amounts of butane added as needed, is shown on Table 4.[20]

TABLE 4—Deasphalting Capacity, 1959

Solvent	B/D
Propane	61,100

Deasphalting is usually carried out in towers. The stage efficiency of these towers frequently is poor. Twenty or more feet of tower height may be needed to be equivalent to one true extraction stage. The process of deasphalting can use considerable improvement. The poor understanding of the phase relationships in a propane deasphalting tower is one of the main reasons why this process is not more efficient.

When deasphalted products are used as feed stocks to catalytic cracking units, a very significant reduction in metal content also occurs. This is beneficial, for these organo-metallic compounds usually are objectionable to the operation of a catalytic cracking unit. They cause more gas and carbon to be produced, and frequently poison the catalyst and upset the product distribution from the catalytic unit.

Solvent-to-oil feed treats with propane, range between 5 and 10 to 1 by volume, depending on the feed and the nature of the product to be made. Extraction temperatures are from about 150° to 180° F with a temperature gradient on the tower. The highest temperature is at the top to produce a sort of internal oil reflux.

Dewaxing. While solvent dewaxing is not the same type of extraction process as is used for treating lube oils, this operation is usually listed along with countercurrent extraction processes.

There have been no outstanding developments in solvent dewaxing in terms of processing or equipment. However, recent work[21] has demonstrated that high-viscosity-index paraffinic stocks boiling in the range of 600° to 1000° F can be dewaxed to produce oils having viscous and not waxy pour points. The viscous pour point for oils made in this way is equivalent to the temperature where the oil attains 200,000 to 500,000 centistokes viscosity. For an oil of 700° to 850° F boiling range, pour points of —65° to —85° F are obtained with ultimate oil yields of 75 to 85%. The experimentally measured viscosities of these oils at —40° or —65° F are from 30 to 50% lower than those predicted by extrapolation on the ASTM viscosity-temperature chart. Thus, if realistic or practical viscosity indexes are calculated, using —65° or —40° F and +210° F as reference points, oils of 120 and higher viscosity index are obtainable. Accordingly, these mineral oils are approaching the best of the synthetics in their physical properties and, with respect to lubricity and oxidative and thermal stability, they can exceed synthetics in many respects, when compounded with the proper additive package.

The dewaxing solvents used to produce these low pour point, paraffinic oils are mixtures of methylethylketone with methyl isobutyl ketone, of methylethylketone with toluene, or of acetone with toluene.

These oils, when further refined and compounded with additives, show good promise as hydraulic oils for military and special automotive use. They may also find application in jet and automotive engines, where low as well as high temperature performance is required.

Table 5 summarizes the current solvent dewaxing capacity.[20] MEK (methylethylketone) mixtures are used to denote ketone solvents generally. Hydrocarbons such as benzene or toluene may be present as co-solvents.

TABLE 5—Lube Oil Solvent Dewaxing Capacity, 1959

Solvent	B/D
MEK mixtures	128,000
Propane	20,300
	148,300

EXTRACTION EQUIPMENT

Early extraction plants were characterized by batch-type extractions. These were replaced to a large extent in the 1930s by continuous-type equipment using plate or packed towers. For the past quarter of a century there have been few radical improvements in extraction equipment.

Packed towers, usually containing Raschig rings, are

used with sulfur dioxide[22] and furfural.[23] Redistribution sections must usually be employed to reduce channeling and its attendant efficiency loss. Plate-type towers are employed in phenol extraction plants where mixing of the two phases is relatively easy but settling is more difficult.

In general, contacting efficiencies of tray-type towers for liquid extraction are on the order of 5 to 10% or less. Conventional packed towers show that the height of a transfer unit is 10 to 20 feet or more.

Mixer-settler units, employing orifice-type mixers or pump mixers with settling tanks, are used in nitrobenzene, copper acetate, and Duo-Sol extraction plants, or where relatively few equilibrium contacts are necessary —as in certain desulfurization extractions.

The rotating-disc contactor (RDC) is a relative newcomer to the extraction scene. The contactor consists of a vertical shell divided into a number of compartments by stator rings. Rotating discs supported by a rotating shaft are centered in each compartment. Oil and solvent flow countercurrently in the apparatus, the rotating discs dispersing the phases.[24]

A number of centrifugal extractors are used commercially[18,25,26] in phenol and in furfural extraction. These have an advantage with respect to space, solvent inventory, and piping. A disadvantage exists in the necessity of requiring feedstocks free from sediments and dirt.

The towers used for Udex extractions (diethylene glycol) are of the pierced-plate type with risers and downcomers for the light and heavy phases.[27]

WHAT THE FUTURE HOLDS

Reliable forecasting is always difficult, but there are a few items that should be mentioned.

While the principles of liquid extraction are not difficult to acquire, it is surprising they are not well understood and applied. Almost all of the easy extractions and extraction plants have been made and built. This extraction industry is shuffling along with a dearth of new ideas.

The future will see many new products made from petroleum. It will be increasingly important to make these cheaply, in high yield, and in high purity. Both the raffinate and extract portions will be new products. Accordingly, the use of compound countercurrent extractors will increase. A compound extractor is one containing both stripping and enriching sections. The efficiency of the enriching section determines extract purity; that of the stripping section determines extract yield.

Processing. It will be of great importance to control the solubility pattern in a countercurrent, multi-stage, compound extractor. The principles and means for doing this are known. Yet they are ignored in many plants. Solubility in the solvent changes rapidly from stage to stage in going from the final enriching stage, to the feed point, and then on to the final stripping stage. The selectivity of a solvent is a very strong function of the amount of material dissolved in it. A solvent's selectivity is directly transformable into capital and operating costs.

As the products made by extraction become more numerous and diversified, the solvent system and the extractor must have a greater ability to handle different products. Particularly in the new products and petrochemical fields, the industry must avoid the term "it's uneconomical" when this lack of profit is based on a new or grass-roots facility. What is needed is a solvent and extractor that can separate a variety of products, using blocked operations to process one material and then another, without needing to build a new extraction plant to get into production.

Extraction systems should have as their target the versatility and flexibility of distillation units. To accomplish this, new solvents and solvent systems should be investigated. The ammonia solvent system[10] is the most flexible of any system yet devised. It gets this flexibility by being able to use anti-solvents and pro-solvents in a single, multistage extractor.

The solution to this problem should not entail a repetition of the rush and confusion that characterized the early 1930s, when solvent extraction of lube oils became commercial. Instead, several of the objectives can be attained by studying more fully the features of solvents now in use, characterizing their pros and cons, and understanding completely the extraction process as it can be best applied to each solvent.

Much of the cost of a solvent extraction operation is in regenerating the solvent for reuse. This is done usually by distillation. New and more ingenious solvent-recovery methods are needed. As more difficult extractions are undertaken, higher solvent treats will be needed. Anything that will allow this to be done, without increasing solvent recovery costs proportionately, is worth-while.

More attention needs to be given to the design of efficient extractors. Today, most of these are "washing" towers. The cost of the extractor is about 25% of the cost of the entire extraction facility. The extractor is the heart of the plant. It determines what can be extracted as well as the yield and purity of the products.

Looking ahead, a well-designed, flexible, adequately-controlled, mixer-settler type of extractor seems to be the best design. This will enable the solubility pattern in the extractor to be optimized to take full advantage of the solvent's selectivity-solubility features. It will enable the best temperature for each stage to be imposed. It will provide precise points for the use of anti- or pro-solvents to make pure extracts and pure raffinates in a single extraction. Such a design should accommodate the widest variety of feed stocks, and permit blocked operations to become feasible.

Mixer-settler extractors need not be complex pieces of machinery with troublesome moving parts. The principal objective is to locate and then maintain the required extraction environment so that the mass transfer operation on each stage is the best that can be achieved at that stage. What is optimum for one stage, may be objectionable on another. The mixer-settler unit appears to be the only way to insure that each stage is doing what it should do for the solubilities and concentrations that are optimum for the solvent.

Pilot-plant mixer-settler extractors should be used more. This is the only way to get the most reliable engineering data for evaluating new extractions and products. The unit should be capable of employing different proportions of enriching and stripping stages, of using variable feed points, of producing any desired solubility pattern in the extractor, and of getting equilibrium and operating-line data on each stage. For complex, multi-component mixtures, such a unit is the best way to find the key pair between which the separation is to be made. One component of the key pair is the compound, or group of compounds, contaminating the extract and preventing it from being purer. The other component of the key pair is the compound desired in the extract, but which is still in the raffinate, thereby comprising a loss in yield for the case where the extract is the desired product.

Products. While catalytic reformates are the only naphthas presently extracted, either for higher octane fuels or petrochemicals, naphtha extraction should be extended to catalytic and thermally cracked naphthas. This will produce new petrochemicals not obtainable from reformates, as well as new fuels. Solvents should be available for use with olefin-containing fractions. Higher-boiling cracked naphthas, upon extraction, will provide extracts of high octane rating or new sources of petrochemicals as well as raffinates for highway diesel fuels.

There is a need for straight-chain, or simply-branched olefins for making improved detergents. These olefins can best be made by thermal cracking of fractions in the boiling range of 700° to 1,000° F. To purify these olefins, or at least free them from objectionable aromatics, solvent extraction appears to be the best process. Such a process does not now exist.

A cheap, versatile extraction process is needed for extracting catalytic cycle stocks to get raffinates of better cracking characteristics, and extracts high in condensed, or nucleated, aromatics for new fuels and chemicals.

It should be possible to develop an extraction process to replace high-vacuum distillation to make various viscosity grades of lubricants, since liquid extraction not only separates by molecular type but also by molecular weight. Present vacuum-distillation processes leave much to be desired from the standpoint of lubricant quality.

The capability and practicality of extraction for producing high-viscosity-index oils, comparable to synthetics, should be examined. It is known that substantial amounts (30 to 50%) of such high VI oils (about 125 and higher) are in many lube fractions. Such a process, combined with deep dewaxing, should provide lubricants competitive in quality with many synthetic oils (ester types) at much lower cost. Because of the greater additive response obtainable with super-refined mineral oils, the cost of the additive package should be less.

As new oxy-compounds from petroleum become more prevalent, there should be more extraction methods available for their purification. The oxy-compounds are those resulting from using the Oxo-process with higher olefins, as well as those made by direct partial oxidation of petroleum fractions.

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Latest Advances in Thermal Diffusion

The trend in thermal diffusion is toward more equipment studies rather than specific product studies. Nevertheless, this review tells of applications in the refining and petrochemical industry

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IN THE LAST DECADE, considerable research on liquid phase thermal diffusion has been conducted in university, government and industrial research laboratories. The phenomenon has been proved to be an excellent tool for separating the components of organic liquid mixtures according to their molecular shapes. It is widely used as an analytical tool in research laboratories.

Various investigators have found that certain components may be isolated by thermal diffusion, which would be very difficult or impossible to separate by conventional techniques. This fact has stimulated investigators to develop continuous process equipment for thermal diffusion.

Some novel improvements in both operating techniques and processing equipment have been made. These have resulted in more efficient utilization of heat energy. However, the most work lately deals with the improvement of efficiency for the thermogravitational columns.

At the present time the cost of thermal diffusion lies between that of conventional processes such as distillation, solvent extraction, adsorption, etc. and the cost of chemical synthesis of cheap organic liquids. Therefore, thermal diffusion may be considered today for the commercial isolation of products of premium value.

Two developments were primarily responsible for the upsurge in activity in thermal diffusion research. In 1938 Clusius and Dickel developed the thermogravitational column for separating isotopes. This column was many times more efficient in separative ability because it employed multistaging. During World War II the Clusius-Dickel column was used to prepare concentrates of U^{235} for the Manhattan Project.

Immediately following the war, industrial concerns became interested in the commercial potential of this unique tool. A great part of the work done with the process since 1945 has been devoted to the study of

TABLE 1—Inspections of Asphalt Used [10]

Specific gravity, 77° F	0.997
Viscosity, SF	
at 300° F	110
at 250° F	443
Soft point R & B, °F	119
Penetration,	
77° F—100 grams—5 sec., DMM	88
32° F—200 grams—60 sec.	21
Loss on heating, 325° F, 50 grams, 5 hours, %	0.005
Flash point (COC), °F	660
Fire point (COC), °F	710
Asphaltenes, wt. %	17.6
Resins, wt. %	52.8
Oils and waxes, wt. %	28.6

TABLE 2—Fractions Separated from Commercially Produced Lubricating Oil by Thermal Diffusion[16]

Fraction	Yield % Wt on Feed	Density g/ml	Refract Index n_D^{20}	Mole wt	Sulfur Content % wt	Kin Visc cs at 100° F	Kin Visc cs at 210° F	VI	Cloud Point °F
Feed	...	0.8717	1.4809	368	1.03	35.2	5.51	102	— 2
1	9.0	0.9734	1.5212	374	1.44	2245	28.11	—199	<—80
2	13.4	0.9389	1.5098	372	1.33	187.8	11.14	10	<—80
3	15.0	0.9103	1.4971	370	1.08	80.27	8.25	73	<—80
4	11.6	0.8853	1.4865	368	1.00	48.62	6.12	71	<—80
5	10.3	0.8700	1.4789	368	0.92	34.48	5.25	88	<—80
6	10.4	0.8540	1.4722	367	0.76	26.13	4.63	102	—40
7	9.9	0.8397	1.4656	367	0.40	20.32	4.11	118	—20
8	9.1	0.8281	1.4600	365	0.25	12.59	3.21	139	+4
9	9.4	0.8162	1.4556	363	0.17	12.91	3.30	145	+31
10	1.9	0.8152	1.4537	361	0.23	12.38	3.23	147	+44

separations of complex organic systems. Nearly all this work was conducted in static or batch thermogravitational columns. This research revealed many novel separations which could not be obtained with more conventional techniques.

It was found that the factors influencing liquid phase thermal diffusion were different from those governing extraction, distillation, adsorption, etc. As more and more groups achieved intriguing separation results, it was only natural that attention should shift to studies of continuous methods for carrying out these separations.

Thermal diffusion is an irreversible process in that separation depends on an irreversible flow of heat. The two major cost factors in liquid phase separations are the capital cost of the columns and the heat requirement during processing. A major improvement in column efficiency would result in large savings in both these areas. It appears that the recent studies of equipment characteristics were predicated on a desire to carry out interesting separations on a commercial scale. The results of this work indicate commercialization of this process is not far away.

PRODUCT STUDIES

Most applications of thermal diffusion to petroleum liquids have concerned relatively low viscosity mixtures. However, Gardner et al[10] have separated and characterized fractions of petrolenes from a Mid-Continent asphalt. The effectiveness of thermal diffusion for separating viscous fractions was well demonstrated in this study. The inspections on the feed asphalt are shown in Table 1.

In this study ten fractions were taken from a batch concentric tube column. Fraction 1 is top, fraction 10 is bottom. Each of these fractions was analyzed by infrared spectroscopy, nuclear magnetic resonance, and electron paramagnetic resonance.

The results from each of these analytical methods are shown in Figures 1, 2, and 3, respectively. Infrared studies show paraffinic materials concentrate at the top of the column and aromatics at the bottom. NMR results confirm this.

The EPR results are especially interesting since they indicate that free radical structures concentrate at the bottom of the column. Average structures for the fractions were determined. The hypothetical structures for the top and bottom fractions are shown in Figure 4.

Nathan and Whitehead[16] of British Petroleum studied the separation of lubricating oil mixtures with a thermogravitational column of their own design. A metering pump injecting product into a receiver rack is a feature of this apparatus. Data on the lube oil feed and ten thermal diffusion fractions are shown in Table 2. In this case fraction 1 is bottom, fraction 10 is top.

The results are similar to those previously published by Jones.[13] The structural type distributions in each of the fractions are shown in Figure 5. Similar data are presented for another lubricating oil. In general these results confirm past observations that the VI of lube oil fractions is increased by thermal diffusion, mass of the

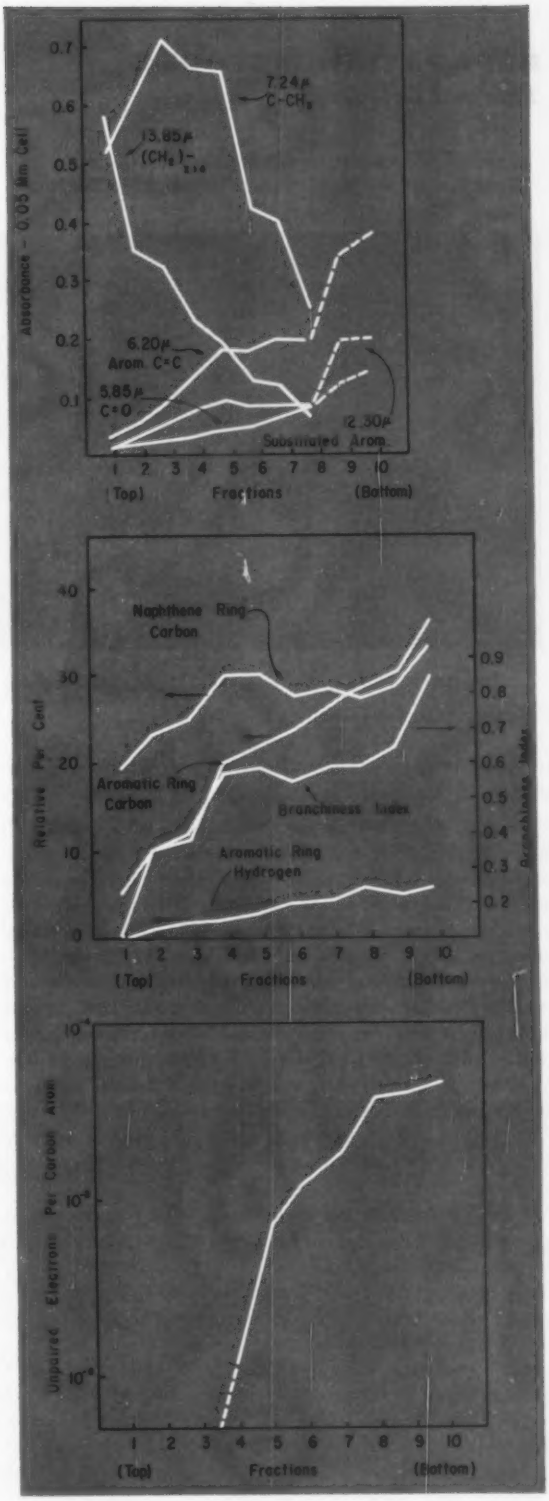

FIGURE 1—Infrared studies[10] show paraffinic materials concentrate at the top of the column. In this plot (top) fraction 1 is the top fraction, and fraction 10 is bottom.

FIGURE 2—Nuclear magnetic resonance data[10] can be used to determine the types of components in each fraction (center).

FIGURE 3—Electron paramegnetic resonance analyses[10] indicate that free radical structures are concentrated at the bottom of the column (bottom).

Hypothetical Average Structures in Fraction 1
($C_{76}H_{150}S_{0.97}N_{0.08}O_{0.3}$)

Hypothetical Average Structures in Fraction 10
($C_{274}H_{262}S_{1.4}N_{1.2}O_{5.7}$)

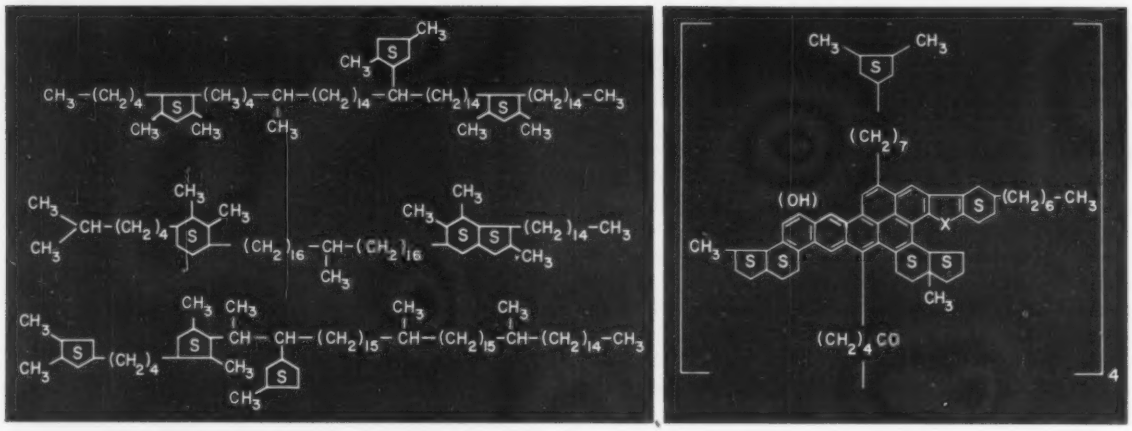

FIGURE 4—Here are hypothetical structures for the top and bottom fractions from a Mid-Continent asphalt.[10]

fractions remains constant, and ring structures are concentrated downward.

In their study of column efficiency, White and Fellows[25] carried out continuous separations of fine complex petroleum fractions; a naphthenic Coastal distillate lube oil stock, a Middle Eastern distillate lube oil stock, a Middle Eastern residual lube stock, a Coastal residual lube stock, and a paraffin scale wax. With the lubes the thermal diffusion was carried out to a level reached by conventional processes. Tables 3 through 6 present the comparisons between thermally diffused and conventionally refined products for each of the four stocks. At constant VI product, the thermal diffusion products are more dense because of a higher aromatic content. Past studies have shown that single ring aromatics may pass into the top thermal diffusion product.[13]

For the scale wax data, the investigators were studying deoiling. This separation is not efficient by thermal diffusion with 50 percent yields of 99.7 percent purity wax requiring 2.8 x 10^6 Btu of heat per gallon of crude wax. The lube oil separations mentioned above required heat input of 200,000 to 990,000 Btu/gal of feed. The transverse flow system described by Frazier[6-8] requires 200,000-300,000 Btu/gal for comparable or somewhat greater separations.[11] Usually thermal diffusion has its best application where other refining processes have reached their limit.

In the AEC work natural uranium with 0.715 percent U^{235} was improved by thermal diffusion to contain 0.86 percent U^{235}.[1] This small change was significant because it allowed an increase of 20 percent in both yield and purity of the output from the succeeding electromagnetic separation system.

Thompson et al[24] discuss the separation of various sulfur-containing mixtures with their continuous-sampled columns. 4-Thiaheptane was nearly completely separated from thiacyclohexane in one run. Comparisons of batch and continuously-sampled columns are given for this binary mixture and for the concentration of sulfur compounds from a crude oil distillate. In both cases larger samples of pure products were obtained from the sampled column.

EQUIPMENT STUDIES

The general trend is toward equipment studies rather than product studies. A monograph on the use of liquid thermal diffusion by the Manhattan Project has re-

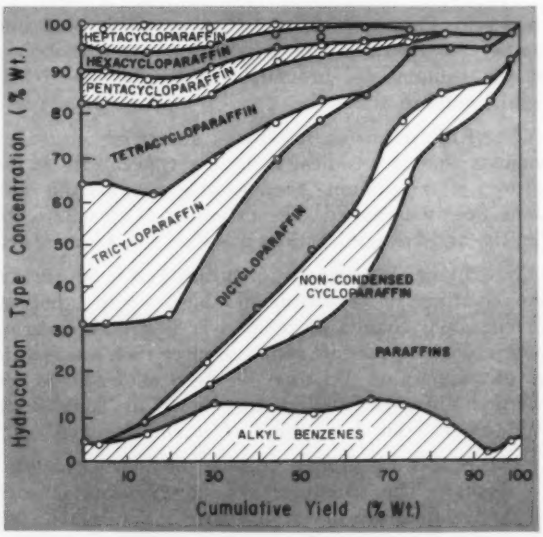

FIGURE 5—After preparing fractions from a commercially produced lubricating oil by thermal diffusion, the hydrocarbon distribution was determined by mass spectroscopy.[16]

TABLE 3—Coastal Distillate [25]

	Raw Distillate	Conventionally Refined	Thermal Diffusion Product
Vis., cs.			
at 100° F	189.0	113.5	107.5
at 210° F	11.6	9.7	9.4
Viscosity index	22	61	60
VTR	—2.53	—2.22	—2.22
Specific gravity, $\frac{20}{20}$	0.9285	0.8984	0.9100
n_D^{20}	1.5104	1.4917	1.5012
S, %	0.27	0.14	0.26
N, %	0.05	0.01	0.04
Aromatics, %	40.3	21.4	35.6
Nonaromatics, %	59.7	78.6	64.4

TABLE 4—Middle Eastern Distillate [25]

	Dewaxed Raw Distillate	Conventionally Refined	Thermal Diffusion Product
Vis., cs.			
at 100° F	43.0	27.2	22.2
at 210° F	5.6	4.9	4.3
Viscosity index	63	115	113
VTR	—1.85	—1.56	—1.49
Specific gravity, $\frac{20}{20}$	0.9200	0.8618	0.8735
n_D^{20}	1.5117	1.4748	1.4850
S, %	2.89	0.73	1.77
N, %	0.08	0.01	0.02
Aromatics, %	54.5	21.7	36.9
Nonaromatics, %	45.5	78.3	63.1

TABLE 5—Middle Eastern Residual [25]

	Dewaxed, Deasphalted Raw Stock	Conventionally Refined	Thermal Diffusion Product
Vis., cs.			
at 100°F	1013	525	436
at 210° F	42.8	31.7	27.6
Viscosity index	78	97	95
VTR	—2.95	—2.55	—2.51
n_D^{20}	.....	1.4949	1.5059
S, %	3.04	1.11	2.52
N, %	.....	0.02	0.05
Aromatics, %	.....	41.9	64.0
Nonaromatics, %	.....	58.1	36.0

TABLE 6—Coastal Residual [25]

	Dewaxed, Deasphalted Raw Stock	Conventionally Refined	Thermal Diffusion Product
Vis., cs.			
at 100° F	1162	681	682
at 210° F	41.1	33.0	32.1
Viscosity index	68	82	79
VTR	—3.03	—2.75	—2.77
S, %	.....	0.57	0.61
N, %	. . .	0.02	0.07
Aromatics, %	. . .	38	45
Nonaromatics, %	. . .	62	55

cently been published.[1] This comprehensive work reveals the events which led to the construction of a full-scale plant for concentration of U^{235} for use in the atomic bomb. This effort is credited with shortening the war by eight days at a cost of $20 million or about 1 percent of the total cost of the project.

The monograph presents an introductory theory of column operation, surveys the literature on isotopic separations, and describes in detail the use of a separation pyramid of thermal diffusion columns. Since the UF_6 work was done at elevated pressures (500-1500 psi), the technical aspects of the operation are described in detail. An automatic product withdrawal device is discussed.[4] This monograph may be the most complete review of the theory and practice of isotopic separations by thermal diffusion.

The use of packing to slow the convection rates in a thermal diffusion column is one possible method for improving the performance of the column. Two papers

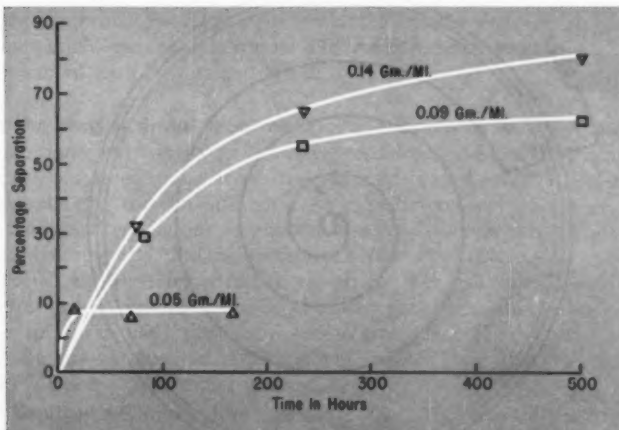

FIGURE 6—Packing improves the performance of a diffusion column. These data (top) were obtained by separating cis- and trans-decahydronaphthelene in a 0.06-inch annulus column.[20]

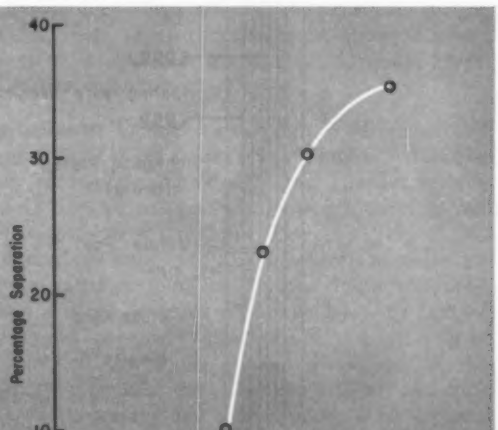

FIGURE 7—No separation is obtained when packing is omitted. (right) These data were obtained in a 0.125-inch annulus column.[20]

SEPARATION METHODS

Thermal Diffusion

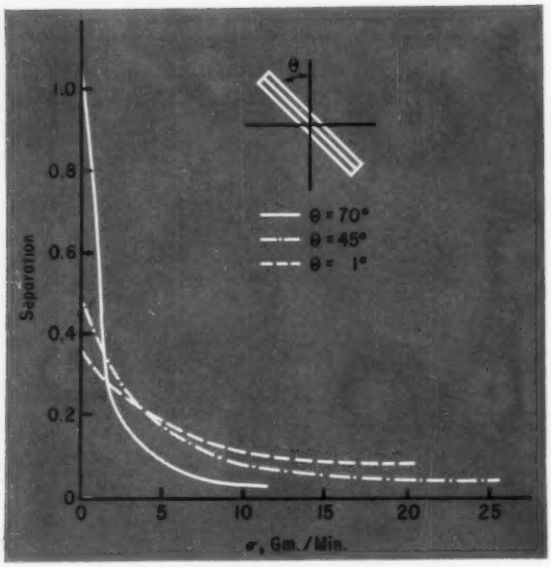

FIGURE 8—Separation rates can be slowed by tilting the column according to these data.[18]

present data on the effect of column packing on separation.[15, 20] Sullivan, Ruppel, and Willingham[20] are concerned with the possibility of increasing slit width and column volume with the introduction of packing.

Since one of the prime technical problems in thermal diffusion equipment is maintaining slit widths of 0.01-inch to 0.06-inch, any technique which allows larger gaps between the hot and cold walls could result in simplification of column construction. In static or batch equipment the larger holdup volume would prove valuable in providing larger samples for analysis. Sullivan et al found that in most cases with slit widths from 0.03 to 0.125-inch the extent of separation increased with increased packing density. However, the rate of approach to equilibrium decreased with packing density. A typical curve is shown in Figure 6.

Columns with gaps as large as 0.06 inch gave no separations with an open annulus but gave good separations when packed. This is shown in Figure 7.

There is some advantage in larger sample volume of an analytical column with packing, but the slow rate of approach to equilibrium probably nullifies the use of packing in a continuous column.

Lorenz and Emery[15] evaluated the effect of packing on continuous column operation. They developed equations to describe a column with reduced convection rates. Separation was found to increase when packing was increased. However, a series of economic calculations showed the cost of performing a desired separation with a packed column is about the same as that for a column without packing. The authors state this is true because industrial packed columns would have nearly the same spacing as open columns.

Powers and Wilke[18] describe another method for slowing the convection currents in thermal diffusion equipment. In flat plate columns, if the unit is tilted at some angle from the vertical with the hot wall uppermost, the convection rate is modified as the cosine of the angle of the column from the vertical. They found,

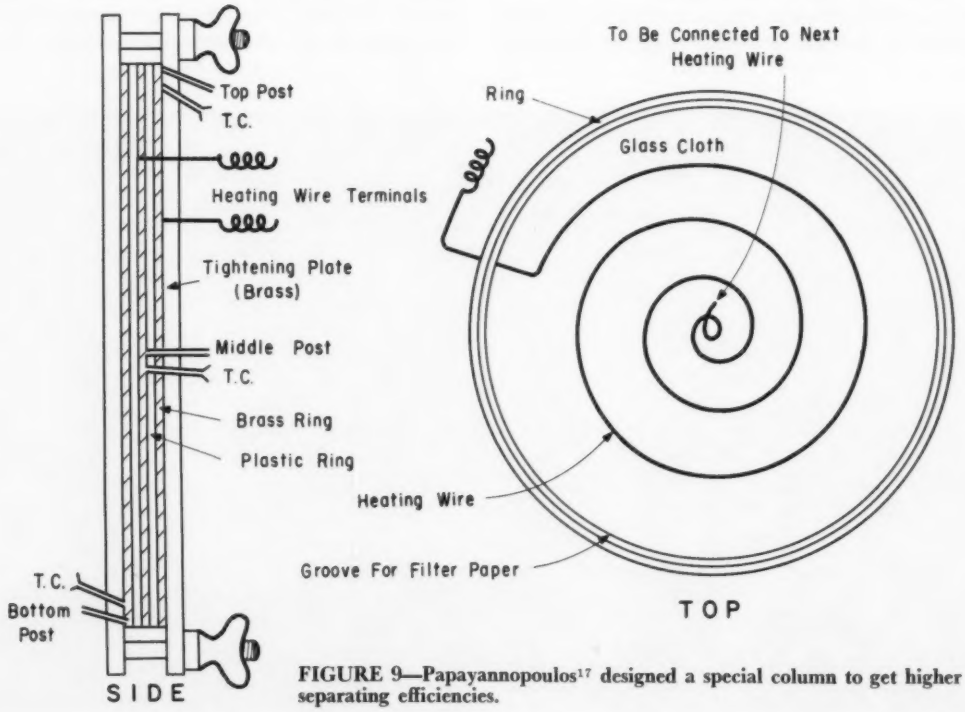

FIGURE 9—Papayannopoulos[17] designed a special column to get higher separating efficiencies.

as expected, that slowing convection rate has the effect of increasing separation at low throughput rates while decreasing separation at high feed rates. Some of their results are shown in Figure 8.

Powers and Wilke conducted a complete study of flat plate columns to check the theory of Furry, Jones, and Onsager.[9] Flow rate, column length, temperature difference, and plate spacing were varied during the studies. There is good agreement between theory and experiment in the range of practical design for industrial units.

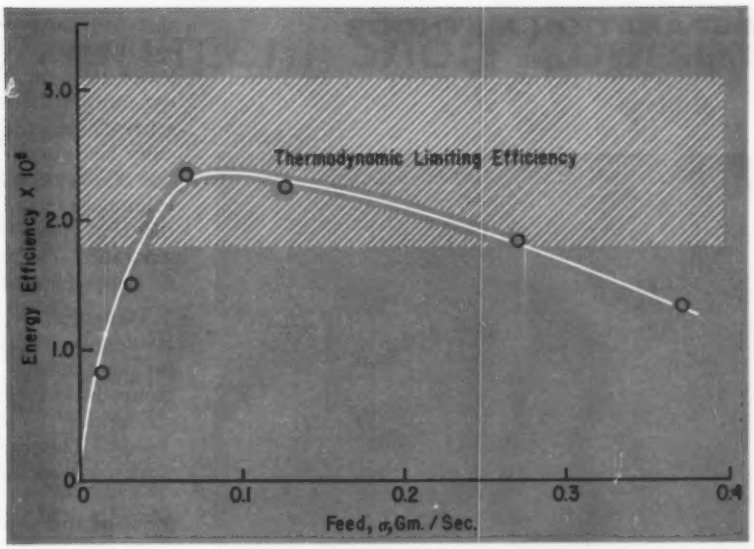

FIGURE 10—Some studies[25] show how close thermal diffusion columns can come to thermodynamic limitations.

An economic estimate is given for a plant to process 1,000 bpd of a 50 percent *n*-heptane-50 percent benzene mixture to yield 500 bpd of a 70 percent *n*-heptane product. This aliphatic-aromatic mixture was chosen because of its analogy to a lubricating oil mixture. The optimum column calculated for this plant was found to be 1.43 cm high and 82.7 miles wide. Since this did not seem practical, a compromise design with 17-foot-tall columns was used. Capital cost was $5,320,000 and processing costs were $0.26/gallon.

Heines, Larson, and Martin[12] also investigated the operating characteristics of columns separating benzene and *n*-heptane mixtures. These authors used concentric tube columns in their study. The variables of number of theoretical plates, temperature difference, takeoff ratio, and slit width were studied for continuous operation. Experimental data were evaluated by the Furry, Jones and Onsager[9] equations. The results are in good agreement with Powers and Wilke.

In the conventional treatment of continuous column operations, most investigators have considered the fluid properties as constant across the plate spacing. Emery[5] has extended the conventional treatment by considering the property variations as temperature varies across the slit. He suggests that in some cases the separation is affected by these temperature variations. For example, for aqueous systems there is virtually no effect while for mixtures with the characteristics of glycerol, the steady state separation is 57 percent greater than that predicted by the simpler theory.

Another technique for increasing the efficiency of continuous column operation is the use of linear shear to change the column flow rates. Ramser[19] has considered the effect of linear shear obtained by uniform motion of the walls of a flat plate column. Ramser compares the rate of equilibration for columns operated under linear shear with those depending only on convection for separation. At viscosities of 0.1 poise, equilibrium is reached more than ten times as rapidly when the average fluid velocity is increased by a factor of 50 through externally applied linear shear. The complexity of building and operating linear shear columns probably rules out the use of this effect in practical columns.

Pulsed pressure waves have been studied because of their usual influence in improving the performance of interface transfer processes such as extraction and absorption. DeMaria and Benenati[3] studied the effect of pulsation on a concentric tube thermal diffusion column. Pulsation decreased separation because of parasitic longitudinal mixing.

At constant frequency the decrease in separation is proportional to the pulse amplitude. At constant amplitude increased frequency decreased separation up to twelve hours of equilibration time but for runs longer than twelve hours, separation increased. Since no interface transfer is involved in thermal diffusion, these results appear reasonable.

A new column of his own design is described by Papayannopoulos.[17] He claims it has a higher separative efficiency than conventional columns. His device is a horizontal, packed column with variable heat input. The apparatus is shown in Figure 9.

The variable heating is obtained by layers of nichrome windings of different numbers of turns. Papayannopoulos compares the operation of this device with that of a conventional concentric tube column. At a given separation level, he claims his column allows use of slit widths thirteen times wider than conventional and consumes 1/40 the energy per unit product. This column is similar in nature to the packed column of Sullivan et al[20] and shows similar improvements over unpacked columns under static conditions. In continuous operation this advantage should be lost. An additional complexity is that at present the Papayannopoulos column can only be heated electrically.

Longmire[14] describes the continuous throughput rec-

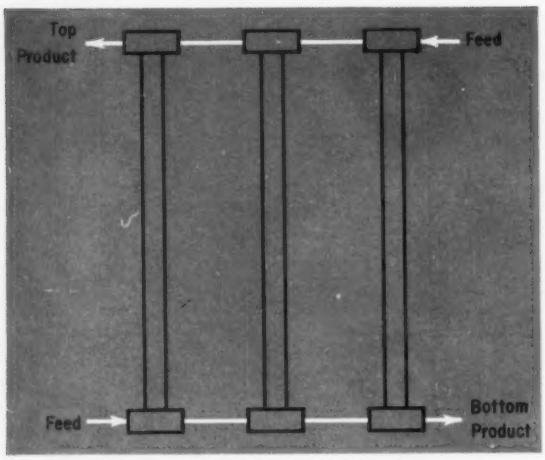

FIGURE 11—Frazier[6, 7, 8] obtained a series of patents relating to a novel end feed system for feeding a group of thermal diffusion columns.

tification of various organic liquid mixtures in thermogravitational columns. He found that for most runs separation was 10 percent greater than predicted by known relations. Wider slit widths gave better separation in continuous operation.

The energy efficiencies of thermogravitational columns were discussed by White and Fellows.[25] In a thermodynamic study backed by experimental operation, these authors concluded that existing thermal diffusion columns are operating near the limiting thermodynamic efficiency and that the controlling factor in separations is the difference in shape between the molecules being separated. Figure 10 is a typical plot from this study illustrating the approach of a practical column to the efficiency limit. Data from this work on the heat consumption required for obtaining certain separations of petroleum stocks are discussed in the product section of this review.

Thompson et al[24] from the Bureau of Mines at Bartlesville describe the design and use of a continuous sampling device for thermal diffusion columns. This motor-driven, syringe type sampler allows slow and continuous removal of product from the ends of a column. This tool has proved valuable in the Bureau's work on separation of sulfur compounds.

Most of the preceding papers concerned center-feed thermogravitational columns. Frazier[6, 7, 8] has obtained a series of patents relating to a novel end feed system for feeding a group of thermal diffusion columns. The flow pattern recommended in these patents is shown in Figure 11.

It has been experimentally verified that 40 percent improvements in separation rate per unit area can be obtained with this transverse flow arrangement as compared with center feed columns. This system may be the most efficient ever suggested for continuous unit operation. A summary of the development of plant scale equipment based on this principle will be presented at the September 1960 meeting of the AIChE.[11] The AIChE paper will include complete economics for lube oil production by thermal diffusion.

A series of patents relating to exchanger type and flat plate type columns was issued during the last two years.[2, 21, 22, 23] With the increasing activity in equipment studies, the patent literature on thermal diffusion devices should increase.

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Corrosion Measurement Short Course

Part 1: Inspecting Corrosion Damage
Part 2: Onstream Corrosion Measurement
Part 3: Finding the Cause of Corrosion Damage

A. J. Freedman, A. Dravnieks and B. Ostrofsky, Standard Oil Company (Indiana), Whiting, Indiana

THE FIRST PART of this series dealt with methods for inspecting corrosion damage which already has occurred in the plant. It covered the modern techniques and tools used to make manual thickness measurements, ultrasonic thickness measurements, and radiation methods for measuring the thickness of materials.

This part covers two means of measuring the corrosivity of process plant fluids—the direct method, by measuring corrosion on specimens exposed to the fluids in the equipment and the indirect method, by measuring the chemical and physical characteristics of the fluids.

MEASURING CORROSIVITY OF PLANT FLUIDS

Corrosion Coupons. Testing with coupons was for many years the only accepted method for determining the resistance of materials to attack by corrosive environments. Coupons of any material, metallic or nonmetallic, can be placed in the desired fluids, on either a laboratory or a plant scale. These coupons will indicate accurately the effects of the environment on the coupons at the point of insertion. In addition to general corrosion, some of the many special types of localized attack that can be observed in this way are: pitting; intergranular and transgranular stress corrosion cracking; embrittlement; selective corrosion of alloys (as, for example, dezincification of brass); and, for non-metals: swelling; softening; crazing; surface spalling; and other types of physical changes.

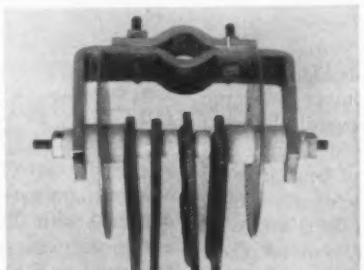

FIGURE 8—Specimen holder clamps on vertical member in large vessels.

General surface corrosion is the only type of attack that can be determined accurately with coupons by weight loss measurements alone. General corrosion refers to uniform surface attack with no specific localized effects of any kind. In order to estimate other types of corrosion damage, additional measurements are needed. These measurements may include tests for hardness and brittleness, and many types of visual examinations, ranging from simple inspection of the surface for evidence of pitting to careful microscopic and X-ray studies of the internal structure of metal coupons. Tests of this nature require complicated laboratory facilities, and the results should be interpreted by engineers skilled in both corrosion and physical metallurgy.

Corrosion coupons are the best method presently available for measuring long term general corrosion rates in process equipment. Coupons can be enclosed in a unit at almost any point where corrosion is likely to occur. It is important to place the coupons as close as possible to the point at which measurements are desired (that is, near vessel walls, trays, tube sheets, etc.). The conditions of exposure, including flow rates, corrosive components, accumulation of corrosion products, and formation of protection films then should be similar on both the coupons and the metal structure.

Temperature also should be comparable except when heat exchange surfaces are involved. In the latter case, the temperature difference between the walls of exchanger or furnace tubes and the corrosive fluid can create unusually corrosive conditions that can not be duplicated on coupons in the stream. Sometimes special laboratory experiments can be devised to duplicate the conditions on heat exchange surfaces in specific locations.[7] Usually, however, corrosion damage in these situations can be measured accurately only by inspections of the actual equipment involved.

Another factor likely to cause differences between corrosion rates measured on coupons and on plant equipment is that of metal structure and composition. This factor is particularly important when so-called "internal corrosion," such as stress corrosion cracking, is involved. Relatively small differences in the amounts of minor alloying elements present can have important effects on the resistance of an alloy to cracking. Also, corrosion resistance can be affected seriously by differences in heat treatments and fabricating procedures (such as welding) used on the unit and on the coupons.[8] It usually is impossible to obtain corrosion coupons made from the same heats and treated in the same way as the metal used for construction of a unit. Compromise is necessary, and it is important that any corrosion prevention program developed from coupon tests be sufficiently broad in scope to cover these differences.

1. Selection, Preparation and Mounting of Coupons. The process of obtaining and mounting test coupons for corrosion studies actually is much more complicated and critical than may appear from first glance. This is particularly true when an extensive evaluation program is planned, involving long-term testing of many different alloys and heat treatments.

Proper record-keeping is of the utmost importance. Each metal plate received from the supplier should be coded for easy identification, and all corrosion coupons cut from each plate should be similarly coded. A com-

plete chemical analysis should be obtained on each plate. This is particularly important when alloys with very similar compositions, such as normal and LC grades of stainless steel, are involved. As was pointed out above, minor composition differences of this sort can have large effects on corrosion rates. Hence, it is essential to relate the corrosion to the actual composition of the material involved.

Corrosion specimens will vary in size and shape, depending upon the nature of the test involved. When weight loss measurements of general corrosion are the prime consideration, it is desirable to use flat specimens with large surface areas. One-eighth inch thick specimens are quite common. However, other factors, such as effects of welding, often need to be considered. In such cases, it may be necessary to use thick specimens in order to provide heat distributions during fabrication which are comparable to those in the plant equipment.

Surface preparation for refinery corrosion coupons is not critical, since corrosion in the surface layers usually is a minor fraction of the total corrosion on the specimen. Some reproducible treatment, such as pickling or sandblasting, is desirable, followed by solvent washing to remove protective grease films. In laboratory work, however, high sensitivity is desired for short-term testing. Corrosion in such tests occurs mostly on the surface layers of the coupons. Hence the coupons must be treated very carefully to remove protective and passivating films and prepare a uniform, reproducible and sensitive surface. In addition to the techniques listed above, vacuum-annealing to relieve surface stresses often is used as a final treatment for laboratory coupons.

The type of mounting rack used for corrosion coupons will of course depend upon the particular location involved. Standardized test spools described by the ASTM are available commercially, and other types of mounting devices are discussed in the "Corrosion Handbook."[10] Figure 8 illustrates a specimen holder designed for clamping on any suitable vertical member in a large vessel. Note that this rack contains several different sizes of specimens, including large disks for weight loss tests and thick welded pieces for study of heat affected zones. Tetrafluoroethylene spacers and sleeves are used to insulate the samples. When galvanic effects are to be investigated, a spacer may be replaced by a metal piece. Alternately, the two dissimilar metals can be welded or clamped together, or joined electrically by wires. Figure 9 shows a similar device designed for mounting specimens in a pipe coupling with at least two inch inside diameter.

Sometimes, retractable coupons can be fastened on a long rod and inserted through a packing gland and gate valve. These coupons can be removed from the unit for inspection while the unit is onstream. Figure 10 shows a typical retractable coupon holder. However, coupons used in this way have serious disadvantages and should be considered only in special circumstances (see below).

2. Coupon Weight Loss Data. The determination of a corrosion rate with coupons depends upon careful measurements of weight loss during exposure. Weight gain experiments, in which the corrosion rate is calculated from the weight of the coupon plus the accumulated products, are practical only in the laboratory, where corrosion products sometimes form as definite compounds, uncontaminated by coke, sludge, and other inert material.

In order to measure the weight loss which occurred on a coupon, it is necessary to remove all accumulated corrosion and fouling products. This procedure invariably introduces errors. Coupons can be cleaned mechanically, by scraping, brushing, sandblasting, etc; or chemically, by washing in solvents or pickling in inhibited acids or alkalies. With all of these methods, however, it is possible either to leave some corrosion products untouched, or to remove some sound metal along with the products. The latter type of errors can be minimized by running the same cleaning procedure on blank (unexposed) coupons and applying any necessary corrections. Nevertheless, with any coupon weight loss measurement, it is advisable to carry out the test over a time sufficiently long to make the cleaning errors a small fraction of the total weight loss.

Most long term corrosion coupons are examined only during annual turnarounds. However, as was pointed out above, small coupons sometimes are used on retractable coupon changers as shown in Figure 10. It often is tempting to use retractable coupons of this type for general corrosion rate measurements on a short term basis. Cleaning and weighing errors introduced on these small coupons can make such data quite unreliable. It is much better to use corrosion probes (see below) for "in situ" studies of corrosion rate changes on a short term basis. Retractable coupons are useful, however, for studying pitting, cracking, and other forms of internal corrosion, since the chance of such an effect occurring and being observed on a coupon is greater than on the much smaller corrosion probe specimens.

Finally, it is essential to remember that coupon corrosion rates indicate only the attack of the environment on the coupons themselves, at the point of installation. Conditions of flow, temperature, concentration, etc. may change considerably only a few feet away from the coupons, with resulting differences in corrosion rates. Also, as was pointed out above, differences in metal composition and physical structure can have large effects on corrosion rates. For these reasons, corrosion coupon data are best handled on a relative basis. Data obtained with different metals, or with the same metal under different process conditions, can be compared and used as a basis for selecting the most likely materials and process conditions for unit operations.

Corrosion Probes. Electrical resistance corrosion probes are simply a form of corrosion coupon, on which metal loss is determined not by weighing in the conventional manner, but by observing a change in the electrical resistance of the specimen. When the specimen corrodes, it becomes thinner, and its electrical resistance increases. From this increase, it is possible to calculate the amount of metal lost from the specimen. Hence the resistance measurement is a sort of "electrical weighing" technique.

Since the resistance of the specimen is affected by temperature as well as by corrosion, a second specimen usually is placed in series with the corrosion specimen, but protected from the stream. This so-called "reference" specimen is used to provide automatic temperature compensation. Sometimes, in laboratory work, ex-

periments can be carried out at constant temperature. In such cases, simpler probes with no reference specimen can be used. Previous publications have discussed these methods in detail.[11-13]

Measuring Instruments. Most corrosion probe measuring instruments are built into small, portable boxes that can be used in the laboratory or carried about in the refinery. Figure 11 shows a typical measuring instrument. Automatic recording console models also are available that can make a continuous record of corrosion on as many as twelve probes simultaneously.

To connect the measuring instrument to the probes, extension cables are used. When the probes are in inaccessible locations, these cables usually are left in place while the probe is installed. The cables must be specially wired to prevent pickup of stray alternating currents from nearby electrical equipment. Also, the cables must be protected from contacting hot lines and from dangling freely in high winds.

Most modern instruments supply low voltage, low amperage alternating current to the probe, although direct current systems also have been employed. Usually, a Wheatstone or Kelvin bridge circuit is used to compare the resistances of the exposed and the reference specimens. Potentiometer-type circuits also can be used. The operation of these instruments is simple, fast, and reliable. As little as 30 seconds may be needed to connect the instrument and complete a corrosion reading on one probe.

FIGURE 9—Specimens can be mounted in a pipe coupling two inches I.D. and larger.

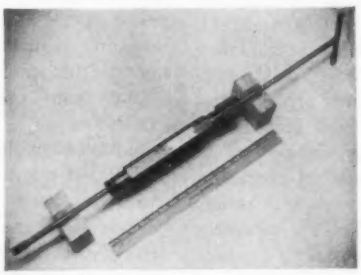

FIGURE 10—Retractable coupon holders can be inserted through a packing gland and gate valve.

FIGURE 11—Corrosion probe measuring instruments are built into small portable boxes.

Probe Design. Corrosion probes are available for use under all conditions of temperature and pressure normally encountered in a refinery. Figures 12, 13 and 14 show three typical designs. Various plastics, enamels and ceramics are used to pack the probe body and protect the reference element from corrosion. Some systems use two reference elements in series, to provide a check on the efficiency of the protection. It is unlikely that a flaw in the protective coating would be exactly alike on both specimens. Hence, if the resistance ratio of the two reference specimens remains constant while the probe is in use, it can be assumed that the protective coatings are satisfactory.

In order to assure a long life expectancy for corrosion probes in process units, thick specimens are desirable. On the other hand, thin specimens provide the most sensitivity to small changes in thickness and hence to low corrosion rates. Thus it is necessary to compromise between the life expectancy and sensitivity desired on any given probe. It has been found that weight loss and electrical resistance measurements give identical results until about ¼ of the specimen thickness has corroded away. Beyond that point, non-uniform corrosion over the surface of the specimen tends to distort the electrical resistance readings. Thus, for example, a 40 mil (0.04 inches) wire specimen can be used reliably until about 10 mils total corrosion have been measured. Specimens of this size are used frequently, since they are sturdy and possess a satisfactory life span. For example, at an average corrosion rate of 0.01 inches per year, a 40 mil wire specimen would be useful for about 1 year.

One way to avoid the sensitivity vs. life span compromise is to use retractable corrosion probes that can be inserted and removed from operating process units. Two such probes are shown in Figures 15 and 16. The probe shown in Figure 15 is inserted and removed through a gate valve and packing gland in the same way as the retractable coupon holder described previously. Above about 150 psi, this probe becomes difficult to insert against the internal pressure. Above this pressure, the probe shown in Figure 16 can be used. In this device, pressure-sealing is accomplished inside the special nozzle, so that the valve used during the insertion process can be removed if desired. A specially-designed retriever, which equalizes pressure on both sides of the probe without allowing leaks, must be used to insert equipment into this nozzle.

Sensitivity. One of the biggest advantages of corrosion probes over other methods for detecting refinery corrosion is their high sensitivity. Electrical resistances can be compared very accurately, so that small amounts of corrosion can be detected readily. Under well-controlled conditions, a resistance change of 0.01 percent can be observed easily. With a laboratory specimen 0.001 inches thick, this means that a decrease in thickness of 5×10^{-8} inches can be detected. This corresponds to the loss of a metal layer only a few atoms thick. Under refinery conditions, such sensitivity is not attainable. As was pointed out above, thicker specimens are needed to give mechanical strength and longer life. Also, non-compensated temperature fluctuations and other uncontrollable sources of error complicate the picture. However, a resolution of 0.2 microinches (2×10^{-7} inches) still is not unusual, and 1-2 microinches is commonplace in refinery measurements. Even assuming the latter limit of sensitivity, a corrosion rate of 0.01 inches per year can be detected from measurements taken only a few hours apart.

Probes vs. Coupons. As was pointed out above, corrosion probe data are directly comparable to coupon

weight loss measurements. That is, the change in resistance of a specimen is related directly to its change in weight. Probes and coupons have, ultimately, about the same sensitivity for long range experiments. The main differences lie in the speed and accuracy that can be achieved by each method.

For example, it can be shown that at a corrosion rate of 0.01 inch per year, a typical retractable coupon, 0.5 x 3 inches, will lose 10 mg. per day. Over a one day exposure at this corrosion rate, only very small amounts of corrosion products will accumulate on the coupon. Hence the errors introduced in cleaning the coupon will be large and variable and may overshadow completely the 10 mg. absolute weight loss. Much longer times would be required to provide satisfactory accuracy in this weight loss determination.

On the other hand, a typical corrosion probe specimen exposed to these same conditions will increase in resistance from 0.2 to 1 percent per day, depending on the initial thickness. Since the accumulated corrosion products generally have much higher electrical resistances than the metal, they do not affect the readings and can be ignored. No cleaning is necessary. The accuracy of the resistance determination is influenced only by the measuring instrument used and by any non-compensated temperature fluctuations which occur during the brief time required to read the meter. Errors of 1 percent in this measurement are unusual.

In addition to this advantage of corrosion probes over retractable coupons, the convenience of measurement should be considered. Corrosion probe data can be obtained in a few minutes time each day. Coupons, however, must be retracted and replaced, sometimes in difficult or dangerous locations. Then the used coupons must be carried to the laboratory for sometimes laborious cleaning and weighing operations.

Thus, corrosion probes provide much greater sensitivity, accuracy and convenience for frequent measurements of corrosion rates. This does not mean that probes can or should replace coupons in all applications. Corrosion coupons remain the best method for obtaining long-term average corrosion rates in process units. Because of the relatively large surface area of coupons, most of the effects of the corrosive medium, including general corrosion, pitting, selective corrosion, and various types of cracking, all can be observed more easily than on probe specimens. Large samples of corrosion products can be produced on coupons, and the nature of the scales (protective, flaky, etc.) can be observed.

Corrosion probes, on the other hand, are invaluable for short term testing to find solutions for sudden corrosion failures, or for longer term experiments designed to determine the effects of process variables on corrosion rates. Also, corrosion probes installed at sensitive locations in new units act as monitors to warn of any sudden change in corrosivity of the stream. With advance warning of this type, it usually is possible to correct the situation and avoid sudden, often disastrous, corrosion failures. Many examples of these applications have been described.[7,13]

It must be remembered that corrosion probes, as well as coupons, can indicate only the actual corrosion rates on the probe specimen at the point of insertion. These rates do not necessarily correspond exactly to general corrosion rates in an operating unit. This is not a serious difficulty, since in most cases, only comparative changes in rate are desired. However, since the probe specimen generally is placed close to the vessel wall and is made from the same material as the vessel unless other metals are being tested, probe results and actual plant corrosion rates have shown very good agreement.

Safety Considerations. In more than five years of accumulated operating experience with corrosion probes, there has never been a reported accident that could be traced to the presence of a corrosion probe in the area. Nevertheless, the probes and measuring circuits are electrical instruments and should be used with the same precautions applied to any electrical equipment used in a potentially hazardous area.

The potential supplied to an open circuit if a current lead or the corrosion specimen should break, is of the order of millivolts. In exhaustive laboratory tests, the spark produced from a broken specimen did not have sufficient energy to ignite typical explosive mixtures. In normal operation, the instrument itself does not produce an igniting spark, and can be considered as comparable to recorders and thermocouple potentiometers for refinery use. However, breakdowns always can occur. As simple a thing as a loose or broken battery lead can produce a dangerous spark. Therefore, it is essential to observe all of the standard precautions when any electrical instrument is used in a hazardous location.

Indirect Measurements. Basically, if the concentrations of corrosive components or, sometimes, corrosion products in a given stream were known, and enough data could be accumulated correlating corrosion rates with concentrations of the corrosive components, an analysis of the stream would give an indirect indication of its corrosivity at any given moment.

Unfortunately, current knowledge is short of this goal. Nevertheless, determinations of certain chemical or physical characteristics have proven useful in many instances. Before electrical resistance corrosion probes came into use, such determinations were the only available means by which one could "backguess" stream corrosivities in a short time. Although corrosion probes now can determine corrosivities more directly, chemical and physical analytical methods may have their place in many corrosion control cases. Usually, chemical analysts measure a factor which can be directly controlled, and which may be significant in process con-

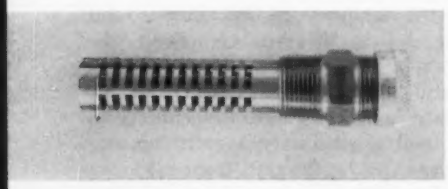

FIGURE 12—This corrosion probe is used for moderate pressure, low temperature applications.

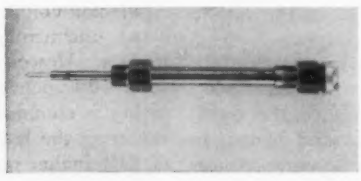

FIGURE 13—A screw-connected probe is used for high pressure, moderate temperature applications.

trol per se. Most chemical tests can be carried out by well-known, traditional laboratory methods.

It is impossible to review all indirect methods. The discussion will be limited only to the most common ones.

Hydrogen Ion Concentration (pH). Hydrogen ion concentration, measured in terms of pH, pH = —log (H^+ concn.) has a well developed meaning, with respect to corrosion, only in aqueous systems. This concept can be applied either to process water drained from condensate drums of various units or to cooling waters. In the absence of other complicating factors, waters become seriously corrosive to steel at pH levels below 4.5 to 5. For admiralty metal, in the absence of ammonia which induces stress-corrosion cracking, the minimum corrosivity range is 8-10. In the presence of ammonia in sulfidic environments, the pH of water in contact with admiralty should not exceed 8.5. Water is "neutral"—neither acidic nor alkaline—at a pH of 7. Certain inhibitors require certain pH ranges for optimum performance.[7] For overhead parts of crude distilling units a pH, of 7-8 is the most common, while some lower pH levels also have been advocated.[14] In cooling waters, pH control is necessary to control corrosion of heat exchangers, carbonate scale deposition, and cooling tower wood decay. Thus, pH is probably the most useful index in corrosion control.

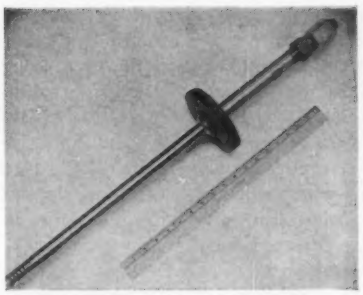

FIGURE 14—Flange-connected probes are suitable for use at 1,000° F and 1,000 psi.

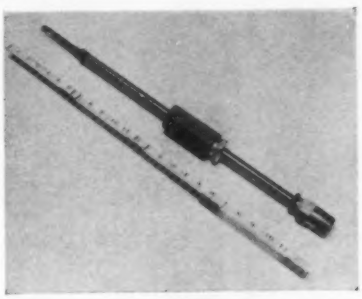

FIGURE 15—Retractable corrosion probes increase the probe life span.

Three techniques are used for pH measurements.

The most accurate and universally accepted method is the electrometric pH determination. This method uses the principle that the electric potential of a cell composed of a pH-sensitive glass electrode and a reference calomel electrode is a function of the hydrogen ion concentration (more precisely, its activity). The sampling may be either continuous, with pH recording, or batchwise. The advantage of this technique is that a definite direct reading, not subject to judgment, is obtained. Under industrial conditions, accuracy of the order of ± 0.1 to 0.2 pH units may be achieved. Precautions, aside from proper sampling and sample storage, involve primarily maintenance of the electrode, which must be clean and should give correct potentials as checked by means of reference solutions.

The simplest, cheapest, and fastest method for pH measurements is the indicator paper technique, in which pH is judged by the color of special pH-sensitive, dye-impregnated paper wetted by the sample solution. This paper is compared with a reference color strip. The method is reliable to not better than ± 0.5 pH unit. Usually the limits are even wider. Colored substances may obscure the color of the paper, many chemicals (e.g. strong oxidizing or reducing agents) may interfere, and the reading is affected by subjective judgment.

The colorimetric technique uses a principle similar to the indicator papers, except that the dye is added to the solution. The color established by pH is measured by an instrument of a visual or photoelectric type, or by a comparison with standards. Although the color measurement is more accurate, turbidity, colored substances, and electrolytes at higher concentrations may interfere.

Sulfur Content. Above 500° F, sulfur compounds in crude oils begin attacking carbon steels. The severity of this attack depends on the total sulfur content, although the form of the sulfur compounds and the presence of other corrosive components also affects the corrosivity. Since the sulfur content depends on the grade of the crude and can not be adjusted for corrosion control purposes, sulfur content usually is not monitored. Rather, materials of construction in the equipment are adjusted, for instance, by switching to units with chrome-alloyed steels, to withstand the corrosive action. There are a number of analytical methods available for sulfur content determinations, including the ASTM D-129 bomb method.

Although consideration should be given to the sulfur content of the crude in estimating its corrosivity, a direct laboratory corrosivity test on the relevant oil fractions seems to be preferable.[15] Such a test would reveal the presence of corrosivity carriers in general, in addition to sulfur compounds.

In catalytic reforming of naphthas to produce high octane reformates, sulfidic corrosion in the presence of hydrogen and hydrogen sulfide cannot be controlled with chromium alloying of steels unless the chromium content exceeds 12 percent.[16-18] The H_2S:H_2 ratio is the fundamentally significant factor at low hydrogen sulfide concentrations.[19,20] However, with the concentration of hydrogen relatively constant, the concentration of total sulfur is the primary index of corrosivity and is controlled by desulfurization. In systems controlled by desulfurization of the feed to the vicinity of the "thermodynamic threshold," carbon steel and low chromium steels chosen to resist hydrogen attack then perform satisfactorily. Procedures for the determination of very low sulfur contents require careful sampling and good analytical technique.

Chloride Content. Most crudes contain inorganic and organic chlorides. In distillation, hydrogen chloride is produced, which combines with water present in the crude or introduced with steam. The resulting hydrochloric acid is one of the principal corrosive agents in any part of the system where aqueous phases may condense.[21,22] This difficulty is considerably reduced by desalting; that is, removal of inorganic salts before the crude is distilled. Scaling by excess salts also is avoided in this way. Thus, desalting is a corrosion control operation, and its efficiency is indicated by the amount of salt left in the crude. The salt content in

crudes may average about 60 pounds per thousand barrels and can reach as high as 200 pounds per thousand barrels. After desalting, the salt content may be between one and four pounds per thousand barrels.

The analytic determination of salts in crude usually is accomplished by diluting the crude with benzene, extracting the salts with distilled water, and analyzing the extract for chlorides and sulfates by common analytical techniques. The determinations serve to monitor the efficiency of desalting and thus are a measure of corrosion control. Since the corrosivity of the overhead streams is related to the salt content only in a general way, pH control, either by caustic or soda ash added to the crude, or ammonia injected into the overhead with or without inhibitors, usually is still necessary. Monitoring with corrosion probes is needed at least to optimize the pH level and the inhibitor injection rate.

Metal Content Analysis. In analyzing a refinery effluent stream for metals such as iron, one does not look for the concentration of a corrosive component. Instead, one assumes that a steady state has been established, in which all metal consumed by corrosion winds up in the form of a corrosion product in the stream. This assumption implies that corrosion product scales or deposits in the equipment release into the stream per unit time as many pounds as are generated by corrosion in the same time interval, and that the "inventory" of corrosion products adhering to the vessel walls remains constant.

Under ideal conditions, the method can provide data on the instantaneous corrosion rates in a piece of refinery equipment which is on-stream. It is used quite widely in refineries on water phases of overhead systems, as well as on hydrocarbon effluents at other points. The determination of iron is done analytically, by the phenanthroline method or with a flame photometer. In hydrocarbon streams, the iron usually is in the form of suspended rust or other corrosion products. These suspended particles can be filtered out from light fractions and determined in the filter residue. However, heavier oils have to be either diluted or ashed before the particles can be separated. Sometimes, when admiralty metal condensers are involved, copper or zinc determinations in the effluent may be made. The procedures of determination are routinely analytical.

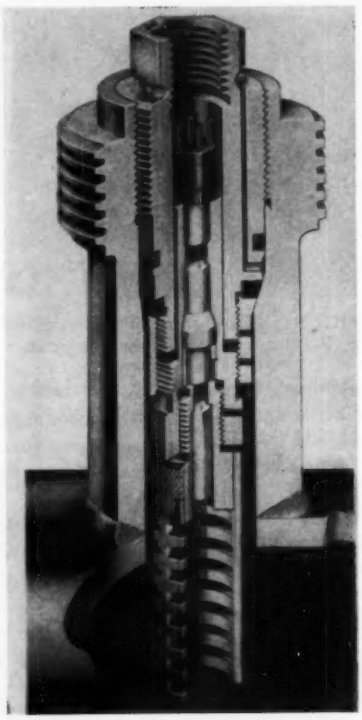

FIGURE 16—This type of retractable probe can be used at pressures up to 10,000 psi.

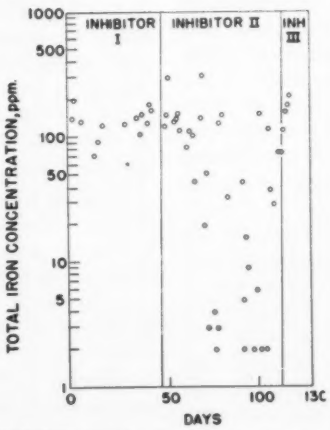

FIGURE 17—An analysis from a crude distillation overhead system shows the iron concentration to vary widely.

There are a number of serious limitations to the method of monitoring corrosion rates by iron analyses. Some of the most important of these are:

- Iron corrosion products, such as the various types of oxides $Fe(OH)_2$, $Fe(OH)$, Fe_3O_4, $Fe(OH)_3$ are completely soluble in aqueous phases only at pH levels below 4.5. In the normally maintained pH range above 6, rust deposits always are present on the equipment walls. Rust is detached from the walls sporadically, so that iron contents, composed of dissolved iron salts plus discrete rust particles, fluctuate widely (see Figure 17). In high temperature sulfide corrosion in a furnace, only a small fraction of the sulfide scale ever is shed into the oil stream.
- The iron content of a refinery stream represents, at best, the average corrosion rate of the whole piece of equipment, and thus gives little information if only a small part of the equipment, for instance one of two upper trays of a tower in the zone where liquid water can exist, is attacked.
- The iron content of importance for a given unit, e.g., a tower is not the total iron, but the incremental increase in iron content when the stream passes through the tower. To obtain this, the iron content picked up by the feed in storage and in previous units, has to be subtracted from the total iron content. This complicates the deductions and makes the data much more uncertain. For overhead streams, this shortcoming is not so significant, since the iron content of the feed can travel with entrained droplets of oils through the vapor space only to a negligible extent.
- Since at any given time in any unit, there are considerable amounts of rust adhering to the inner walls, any substance which possesses detergency may rapidly release large amounts of rust particles into the stream. Conversely, any large increase in rust content is ambiguous, since it may come from either accelerated corrosion or increased detergency. In the case of increased detergency, it takes days and weeks to arrive at a new steady state involving cleaner walls. When the pH is modified or inhibitors are introduced, detergency changes may obscure corrosion rate changes for a long time.

In general, it appears that the usefulness of metal content analyses in determining stream corrosivities is somewhat overrated and is beset with numerous pitfalls.

TO BE CONTINUED

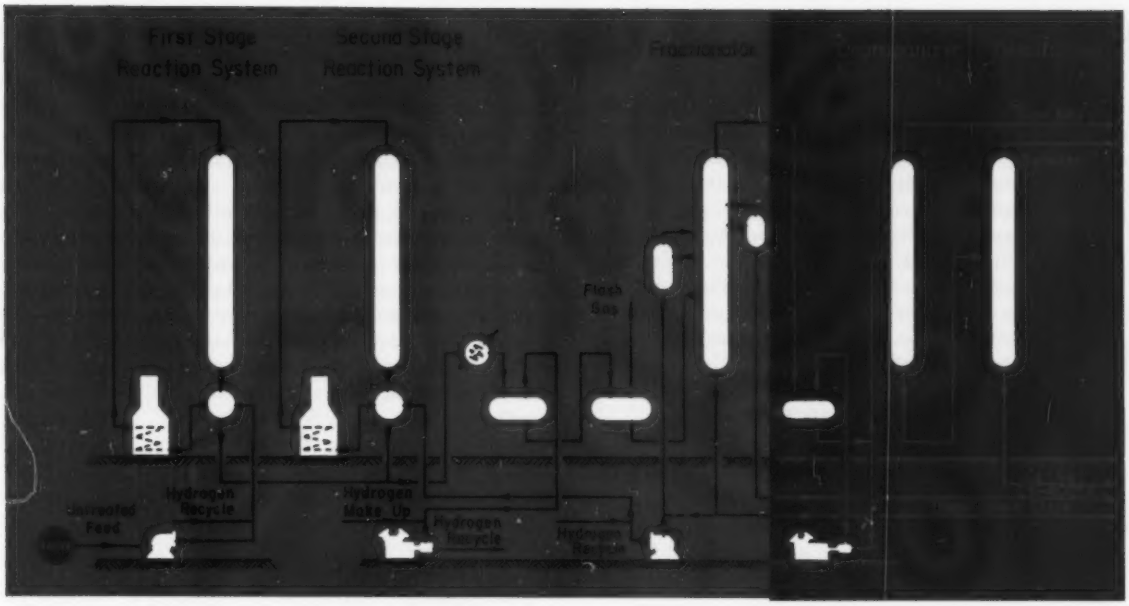

FIGURE 1 Unicracking employs a reactor temperature of 600°-800° F and reactor pressure of 500-2,000 psig. A depropanizer and debutanizer are added to the cost evaluation.

Unicracking Gives New Refining Step

The addition of hydrocracking can give an attractive way to convert marginal or problem cracking stocks. Economic advantages for one of these new processes are discussed here

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UNICRACKING is a new catalytic hydrocracking process, developed by Union Oil Company of California for the efficient and economical conversion of marginal or problem cracking stocks to high quality gasoline and middle distillate products. The process provides a new way to upgrade catalytic cycle oils, thermal and coker gas oils, and heavy cracked or straight-run naphthas. Even when the sulfur and nitrogen contents are high, Unicracking can effectively convert these stocks at a cost which is attractive in today's highly competitive economic climate.

For some time there has been a growing need for a process which can efficiently convert refractory gas oils and heavy naphthas that are unsuitable for catalytic reforming. It is well known that hydrocracking is capable of producing high yields of well refined light and middle distillates without the production of low-value fuel oil. This has been demonstrated earlier both in this country and abroad.[1,2,3,4] However, the high investment and operating costs of earlier hydrocracking processes have prevented their general use.

In spite of the development of improved catalysts having a more specific cracking activity than that exhibited by the early "hydrogenolysis" catalysts, hydro-

cracking processes operating in Europe during and after World War II still required thorough presaturation and refining of the feed to the hydrocracking step.[3,4] Both the pretreatment and hydrocracking stages required pressures in excess of about 3,000 psig for continuous operation. Although the processes using the newer dual-function catalysts (hydrogenation and catalytic cracking activities) produced gasoline of higher knock rating than that of the gasoline produced with the old hydrogenolysis catalysts, they are still too expensive for today's economy.

PROCESS OBJECTIVES

In view of the economic limitations of existing processes, it was clear that a new hydrocracking process had to meet certain minimum objectives to be successful.

- The process must be able to convert refractory gas oils more efficiently than can either thermal or catalytic cracking.
- The catalyst must permit continuous operation for several months at pressures below 2,000 psig.
- The catalyst should be readily regenerable by conventional means to minimize catalyst costs.
- The catalyst should function effectively in the presence of hydrogen sulfide and ammonia so that separate pretreatment of the feed can be avoided.
- The products must give the refiner a quality boost and no fuel oil should be made.

Unicracking fulfills these objectives. In operation, Unicracking is similar to Unifining. Know-how gained in the many years of commercial experience in Unifining has been applied to the process.

BASIS OF THE UNICRACKING PROCESS

The heart of Unicracking is a new catalyst which possesses a balance between hydrogenation and cracking activities. This results in high conversion and maximum selectivity in the production of desirable products. The production of dry gas and coke is negligible. The catalyst is rugged, both from the standpoint of repeated regenerations and of its tolerance toward sulfur and nitrogen compounds. Long life between regenerations and the ability to withstand repeated regenerations by conventional methods lead to low catalyst cost per barrel of feed processed.

The new dual-function catalyst makes possible many desirable reactions which occur only to a very limited extent in straight hydrogenation or in conventional catalytic cracking. Nevertheless, other reactions which are typical of these processes also occur very extensively. Thus, nearly complete desulfurization, denitrogenation, and olefin saturation are obtained in Unicracking. A preponderance of isoparaffins over normal paraffins is found in Unicracking as in catalytic cracking.

Major Unicracking reactions not found in catalytic cracking are complete olefin saturation and the cracking of polycyclic aromatics. Refractory stocks, such as catalytic cycle oils, contain large proportions of naphthalene hydrocarbons and appreciable amounts of higher polycyclic aromatics. Unless these hydrocarbons have long side chains or saturated condensed rings, the principal conversion product in catalytic cracking is coke.[5] Generally, the naphthalene derivatives present in cycle oils are methylnaphthalenes and methyltetralins. Tetralins are considered to be monocyclic aromatics and catalytically crack partially to alkylbenzenes and are dehydrogenated partially to methylnaphthalenes. The latter are extremely refractory toward catalytic cracking and represent a very poor feedstock for the process.

In contrast to catalytic cracking, polycyclic aromatics such as methylnaphthalenes are easily converted by Unicracking. Here they are partially saturated and split to form high-octane monocyclic aromatics, naphthenes, and isoparaffins. For this reason, catalytic cycle oils, which are poor catalytic cracking feeds, are preferred feeds for Unicracking. Similarly, aromatic thermal gas oils, including coker gas oils, are good feeds. High-nitrogen stocks, which are difficult to convert in catalytic cracking because of nitrogen "poisoning," are efficiently converted. Also, high-sulfur feeds are converted to low-sulfur products.

An important feature of Unicracking is the production of gasoline in which the ratio of isoparaffins to normal paraffins is much greater than predicted by thermodynamic equilibrium. This is particularly true of the product obtained from highly aromatic or naphthenic gas oils.

Another important feature of Unicracking is that it produces naphtha of high cyclic content from high cyclic content feedstocks. This, plus the high iso-to-normal ratio of paraffins in the gasoline product, leads to the production of excellent reforming stocks from Unicracking of cycle oil, heavy catalytic gasoline, and other aromatic-naphthenic feedstocks.

PROCESS FLOW

Unicracking is a fixed-bed process which requires infrequent catalyst regeneration. The diagrammatic process flowsheet presented in Figure 1 shows two stages of cracking. Untreated feed is introduced directly into the first-stage reaction system where 30 to 50 percent of feed is converted to gasoline. The reactor effluents from both stages are brought together and after appropriate cooling and liquid-gas separation the liquid enters a common fractionator. The unconverted oil is the feed to the second reaction stage and is recycled to meet fresh feed conversion requirements. In this second reaction stage the conversion to gasoline is 50 to 70 percent per pass. The production of a diesel blend stock as shown on the flow diagram is optional. This ability to produce two major products, gasoline and diesel, demonstrates the adaptability of the process to the refiner's ever-changing product requirements.

Two-stage cracking maximizes liquid yields and on-stream periods between regeneration. This arrangement results in substantial savings in capital and operating costs over processing with separate feed pretreatment. It also minimizes reactor size for a given feed rate and reduces catalyst inventory.

Depending upon the feedstock and the process objective, reactor temperatures range from 600° F to 800° F and operating pressures vary from 500 psig to 2,000 psig. These operating conditions allow the use of conventional refining equipment and mechanical design

throughout the entire plant. The process is also simple to instrument and is readily adaptable to automatic control.

POTENTIAL APPLICATIONS

The process was developed primarily for the efficient conversion of refractory (aromatic) stocks and high-sulfur, high-nitrogen stocks to quality gasoline and middle distillate products. Optimum feed boiling range is usually about 400-600° F. However, this depends on the individual refiner's situation. Refinery stocks of interest in normal order of decreasing aromaticity are:

- Aromatic extract
- Catalytic cycle oil
- Thermal gas oil
- Coker gas oil
- Heavy cracked naphthas
- Visbreaker gas oil
- High-sulfur, high-nitrogen virgin gas oil

The following applications with these types of stocks have been developed and show favorable economics with reasonable product price structure:

- High gas oil conversion (90-100 percent) to gasoline. (Conversion is defined as the disappearance of feed.)
- Intermediate gas oil conversion (50-80 percent) to gasoline with unconverted gas oil upgraded to high cetane premium diesel.
- Conversion of heavy cracked naphtha for volatility and octane improvement.

The chemistry of the process suggests the following possible applications which may be of interest to some refiners:

- Jet fuel production by reduction of boiling range and quality improvement.
- Conversion of highly paraffinic naphthas to high octane light isoparaffins.

One of the basic objectives in developing the process was to reduce fuel oil production. This is accomplished by two mechanisms, namely, conversion of excess cutter stock or heating oil to gasoline and cracking to high conversion levels without producing fuel oil. The resulting higher yield of gasoline and premium mid-barrel at the expense of fuel oil permits reduction of refinery crude rate.

YIELD-QUALITY DATA ON TYPICAL FEEDSTOCKS

Unicracking Catalytic Cycle Oil. One of the principal feedstocks requiring the special features of Unicracking for conversion to gasoline is catalytic cycle oil. A light cycle oil produced in fluid cracking of stocks derived from West Texas crude is described in Table 1. This stock is typical of many produced by mid-continent refiners.

The yields and product quality data from Unicracking this aromatic catalytic cycle oil are also given in Table 1. C_4-400° F EP gasoline was produced at over 120 percent conversion efficiency. This efficiency is defined as the volume of gasoline produced per barrel of feed converted. The dry gas production is low and consists principally of propane. Data are given for butanes, C_5-C_6, C_7-400° F EP gasoline, and diesel stock at 90 percent conversion of the fresh feed.

The C_4, C_5 and C_6 fractions contain a high percentage of high octane isoparaffins. For example, the C_5-C_6 fraction contains 80 percent paraffins but has an octane rating of 98.5 F-1 + 3 ml TEL and a negative sensitivity. The C_7-400° F EP gasoline octane rating is 90 F-1 + 3 ml TEL and contains 75 volume percent aromatics plus naphthenes. This stock reforms to the 102-104 octane level at moderate severity and high yield. The octane of the C_7-400° F EP Unicracked gasoline increases as the aromatic content of the feed increases and octane ratings of the unreformed stock as high as 97 F-1 + 3 ml TEL have been obtained from more highly aromatic catalytic cycle oils.

The diesel product has a cetane number of 72 and is an excellent blending stock. At lower total conversion levels the cetane number is lower and the stock can be produced as a finished diesel or normal boiling range.

Unicracking California Delayed Coker Gas Oil. Coker gas oils are readily Unicracked to high-quality gasoline and mid-barrel products. The high-sulfur, high-

TABLE 1—Unicracking West Texas Fluid Catalytic Cycle Oil

Feedstock	
Gravity, °API	25.9
Distillation, D-158, °F	
Initial	446
10 Percent	468
30	483
50	498
70	516
90	544
Maximum	577
Sulfur, Weight Percent	1.17
Nitrogen, ppm total	70
Hydrocarbon Analysis, Weight Percent	
Paraffins	23
Olefins	7
Naphthenes	12
Aromatics	53
Heterocyclics	5
Yields	
Conversion, FF to 400° F EP Gasoline, Volume Percent	90
Efficiencies, volume percent FF converted	
C_4-400° F EP Gasoline	120.4
C_5-400° F EP Gasoline	105.9
C_7-400° F EP Gasoline	80.3
Yields	
Dry Gas, SCF/B FF	
C_1	1
C_2	11
C_3	65
Total Dry Gas	77
Liquid Product, Volume Percent FF	
Isobutane	7.7
n-Butane	5.2
C_5-C_6	23.0
C_7-400° F	71.7
Diesel Stock	10.7
Total Liquid Product, C_4-plus	118.3
Chemical Hydrogen Consumption, SCF/B FF[a]	2240

Product Quality	C_5-C_6	C_7-400° F Gasoline	Diesel Blend Stock
Gravity, °API	82.0	43.7	40.6
Octane Numbers			
F-1 Clear	86.5	75.0	.....
F-1 + 3 ml TEL	98.5[b]	90.0	.....
F-2 Clear	82.0	69.0	.....
F-2 + 3 ml TEL	99.0	84.0	.....
Hydrocarbon Analysis, Volume Percent			
Paraffins	80	25	.....
Naphthenes	17	47	.....
Aromatics	3	28	.....
Distillation, D-86 or D-158, °F			
Initial	95	224	556
10 Percent	105	248	565
30	114	277	568
50	123	315	570
70	135	354	574
90	152	385	580
Maximum	168	400	630
Cetane Number	.....	.....	72
Sulfur, ppm	25	21	4
Nitrogen, ppm total	.....	0.2	1.1
Pour Point, °F	.....	.....	+40
Ramsbottom Carbon Residue on 10 Percent Bottoms, Weight Percent	.....	.....	0.29
Color, ASTM D-1500	.....	.....	3.0

[a] Includes hydrogen used in chemical reactions and excludes solubility losses.
[b] This C_5-C_6 fraction has a blending octane number of 99.5 F-1 + 3 ml TEL in a typical premium.

nitrogen California coker gas oil described in Table 2 was Unicracked at 75, 85 and 100 percent conversions to 400° F end point gasoline. The three examples illustrate the processing flexibility of Unicracking for producing total gasoline or gasoline plus a premium mid-barrel stock.

In going from 75 to 100 percent conversion of fresh feed to gasoline, the C_5 + gasoline volume increases from 78.8 to 102.2 volume percent of feed while the diesel stock is decreasing from about 25 percent to zero. The C_4 + efficiency is nearly constant over this conversion range. Somewhat higher hydrogen consumption and dry gas make is evident as total conversion is raised.

Product quality data are given for the C_5-C_6 fraction and the C_7-400° F EP gasoline from Unicracking the coker gas oil at 100 percent conversion. As in the case of Unicracking catalytic cycle oil, the octane of the C_5-C_6 fraction is high, 98.3 F-1 + 3 ml TEL and 100.0 F-2 + 3 ml TEL. The C_7-400° F EP gasoline has the very low nitrogen and sulfur content characteristic of Unicracking products. This gasoline contains about 70 percent naphthenes plus aromatics and is readily upgraded by catalytic reforming to octane levels meeting foreseeable premium gasoline requirements.

Properties of the Unicracker gasoline before and after reforming and of diesel produced from operation at 70 percent total conversion are presented in Tables 3 and 4.

The C_7-385° F EP gasoline from Unicracking the delayed coker gas oil was reformed to an octane rating of 101.8 F-1 + 3 ml TEL at a C_5-plus yield of 83.5 volume percent. Because of its lower cyclic content, this naphtha reformed to a slightly lower yield than that obtained from catalytic cycle oil.

The diesel stock from operation at 70 percent total conversion has a 56 cetane number and very low sulfur and nitrogen content. Data for the stock are compared with typical West Coast diesel properties and show the high quality of the Unicracker diesel.

Unicracking Fluid Coker Gas Oil. A highly olefinic, high-sulfur, 600° F EP fluid coker gas oil has also been Unicracked. In comparison with the delayed coker gas oil, the fluid coker gas oil showed a yield advantage of about two volume percent of feed, higher gasoline octanes, and higher hydrogen consumption. Other results are similar. The properties of the fluid coker gas oil are given below:

Gravity, °API	26.7
Boiling Range, D-158, °F	412-598
Hydrocarbon Analysis, vol %	
Aromatics and heterocyclics	51
Olefins	24
Saturates	25
Sulfur, wt %	2.46
Nitrogen, ppm	1260

Unicracking Heavy Catalytic Gasoline. An attractive application of Unicracking is the upgrading of heavy catalytic naphtha from regular to premium

TABLE 2—Unicracking California Delayed Coker Gas Oil

Feedstock			
Gravity, °API			29.7
Distillation, D-158, °F			
Initial			390
10 Percent			447
30			486
50			511
70			538
90			570
Maximum			600
Sulfur, Weight Percent			1.75
Nitrogen, ppm total			1340
Hydrocarbon Analysis, Weight Percent			
Paraffins			17
Olefins			11
Naphthenes			29
Aromatics			31
Heterocyclics			12
Yields			
Conversion, FF to 400° F EP Gasoline Volume Percent	75	85	100
Efficiencies, volume percent converted FF			
C_4-400° F EP Gasoline	117.5	116.6	117.0
C_5-400° F EP Gasoline	104.9	103.3	102.2
C_7-400° F EP Gasoline	81.8	78.7	76.2
Yields			
Dry Gas, SCF/B FF			
C_1	2	2	3
C_2	9	10	12
C_3	46	53	67
Total Dry Gas	57	65	82
Liquid Product, Volume Percent FF			
Isobutane	6.2	7.6	9.4
n-Butane	3.2	3.9	5.4
C_5-C_6	17.4	21.1	26.0
C_7-400° F	61.4	67.7	76.2
Diesel Stock	24.9	14.0	0.0
Total Liquid Product	113.1	114.3	117.0
Chemical Hydrogen Consumption, SCF/B FF[a]	1390	1510	1730

Product Quality (100 percent Conversion)	**C_5-C_6**	**C_7-400° F Gasoline**
Gravity, °API	82.5	48.4
Distillation, D-158, °F		
Initial	96	225
10 Percent	109	251
30	116	276
50	125	307
70	138	344
90	155	383
Maximum	177	400
Octane Numbers		
F-1 Clear	85.2	63.3
F-1 + 3 ml TEL	98.3	82.1
F-2 Clear	81.4	60.7
F-2 + 3 ml TEL	100.0	80.0
Hydrocarbon Analysis, Volume Percent		
Paraffins	73	31
Naphthenes	24	54
Aromatics	3	15
Sulfur, ppm	5	1
Nitrogen, ppm total	.....	0.4

[a] Includes hydrogen used for chemical reactions but excludes loss by solubility.

TABLE 3—Reformability of Unicracked Gasoline from California Delayed Coker Gas Oil Reformed at 500 psig

	Unicracked Gasoline—Reformer Feed C_7 to 385° F.	Reformed Gasoline Product-C_5+
Yield, C_5+ volume percent feed	.....	83.5[a]
Yield, C_4, volume percent reformer feed	.....	7.2
Gravity, °API	47.5	.....
Distillation, D-86, °F		
Initial	222	108
10	250	181
30	273	242
50	304	278
70	335	320
90	364	357
Maximum	384	446
Sulfur, ppm	15	nil
Nitrogen, ppm total	0.2	nil
Hydrocarbon Analysis, volume percent		
n-Paraffins	6	29
Isoparaffins	23	
Naphthenes	49	8
Aromatics	22	63
Octane Numbers		
F-1 Clear	66.0	96.8
F-1 + 3 ml TEL	83.0	101.8
F-2 Clear	61.8	83.0
F-2 + 3 ml TEL	79.4	90.8

[a] Splitting the C_7 to 385° F full-range feed and reforming the light fraction at 275 psig and the heavy fraction at 500 psig results in a one percent yield improvement over the data shown.

TABLE 4—Premium Diesel from Unicracking California Delayed Coker Gas Oil at 70 Percent Conversion

	Unicracked Diesel	Typical West Coast Domestic Diesel (1960)
Gravity, °API	35.8	31.0
Distillation, D-158, °F		
Initial	400	430
10	430	500
30	470	.....
50	510	570
70	550	.....
90	580	640
Maximum	610	680
Sulfur, weight percent	0.003	0.5
Nitrogen, ppm total	4	.....
Pour Point, °F	—5	+20
Cetane Number	56	47
Ramsbottom Carbon Residue on 10 percent Bottoms, weight percent	0.10	0.16
Color, ASTM D-1500	1.5	2.0

TABLE 5—Unicracking Heavy Catalytic Gasoline

Feedstock	
Gravity, °API	33.2
Distillation, D-86, °F	
Initial	358
10 percent	373
30	387
50	398
70	410
90	436
Maximum	467
Octane Ratings	
F-1 Clear	86.0
F-1 + 3 ml TEL	92.6
Sulfur, weight percent	0.505
Nitrogen, weight percent total	0.110
Hydrocarbon Analysis, volume percent	
Paraffins	16
Naphthenes	11
Aromatics	54
Olefins	19

Product Quality	Reformer Feed Unicracked Naphtha C_7-335° F.	Reforming Data C_5+
Yield, volume percent reformer feed		
C_5-plus	.....	90.0
Butanes	.....	3.1
Gravity, °API	44.8	.....
Octane Numbers		
F-1 Clear	86.2	101.7
F-1 + 3 ml TEL	93.8	104.1
Hydrocarbon Analysis, volume percent		
n-Paraffins	8	21
Isoparaffins	16	
Naphthenes	37	3
Aromatics	39	76

TABLE 6—Catalytic Cracking Comparison Between Unifined California Heavy and Full-Range Gas Oils

Feedstocks	Full-Range Gas Oil	Heavy Gas Oil
Volume percent of full-range	100	36.9
Gravity, °API	31.0	25.3
Distillation, D-158 or D-1160, °F		
Initial	244	526
10	432	655
30	510	680
50	570	700
70	628	730
90	698	780
Maximum	746	855
Sulfur, weight percent	0.14	0.16
Nitrogen, weight percent	0.184	0.273
Conversion, volume percent Feed	50	50
Product Yields, volume percent Feed		
Butanes	9.7	11.0
Light Gasoline (C_5-320° F EP)	22.0	26.5
Heavy Gasoline (320-400° F EP)	6.8	5.7
Total Gasoline (C_4-400° F EP)	38.5	43.2
Carbon on Catalyst, weight percent feed	7.2	9.2
Efficiency (C_4-400° F EP Gasoline)	77.0	86.4
Product Properties		
Light Gasoline, C_5-320° F, F-1 + ml TEL	99.0	99.6
Heavy Gasoline, 320-400° F, F-1 + 3 ml TEL	98.8	100.8

grade blending stock. Increased volatility and improved quality may be attained without loss of total gasoline volume. The example shown in Table 5 illustrates the processing of a heavy catalytically cracked naphtha which is unsuitable for premium gasoline blend stock and too heavy for reforming. These data were obtained from once-through bench-scale operation. The C_7-335° F EP gasoline product from Unicracking was reformed and a typical yield-octane relationship is shown. These high-quality products may be used in premium grade gasoline displacing inferior grade materials to regular gasoline. In addition, due to the improved volatility of the Unicracked stock, high-octane, low-volatility stocks employed in regular gasoline blends may be shifted to premium grade gasoline.

Combination Catalytic Cracking of Heavy Gas Oil and Unicracking of Light Gas Oil. An inherent advantage of installing a Unicracker for the light gas oils is the improved performance of the cat cracker on the heavy gas oils compared to the full-range gas oils. A feedstock investigated for Unicracking was the light (600° F minus) coker, cat cracker, and high-sulfur, high-nitrogen virgin gas oil from an existing refinery. This refining case showed very favorable economics and is described later.

When catalytic cracking of heavy gas oil fractions is carried out, improvements in gasoline yield, product distribution and gasoline octanes are obtained over catalytic cracking of the full-range gas oil either at constant conversion or at constant coke make. Table 6 shows a fluid catalytic cracking comparison between Unifined California heavy and full-range coker gas oils at 50 percent conversion of feed. A similar comparison would be expected with stocks which are not pre-Unifined.[6] This improvement in cat cracker performance when a Unicracker is being considered for all or

TABLE 7—Unicracking Capital and Operating Costs

Unit Size, bpsd	5,000	10,000	15,000	15,000
Conversion, volume percent FF	90	90	90	70
Capital Investment of Boundary Limits Unit, Including First Catalyst Charge	$3,800,000	$6,400,000	$8,400,000	$7,200,000
Direct Operating Costs, cents/bbl feed				
Operating Labor	3.9	2.9	1.9	1.9
Fuel	7.4	7.4	7.4	6.1
Power	4.9	4.9	4.9	4.1
Cooling Water	1.3	1.3	1.3	1.0
Catalyst	5.9	5.9	5.9	5.1
Maintenance	9.0	7.6	6.7	5.7
Total Direct, ¢/bbl	32.4	30.0	28.1	23.9

Basis for Operating Costs	Dollars/Unit
Operating Labor	90/opr/shift
Fuel	0.25/MM Btu
Power	0.007/KWH
Cooling water	0.015/M Gal
Maintenance	4 percent investment/Year

Unicracking Gives New Refining Step . . .

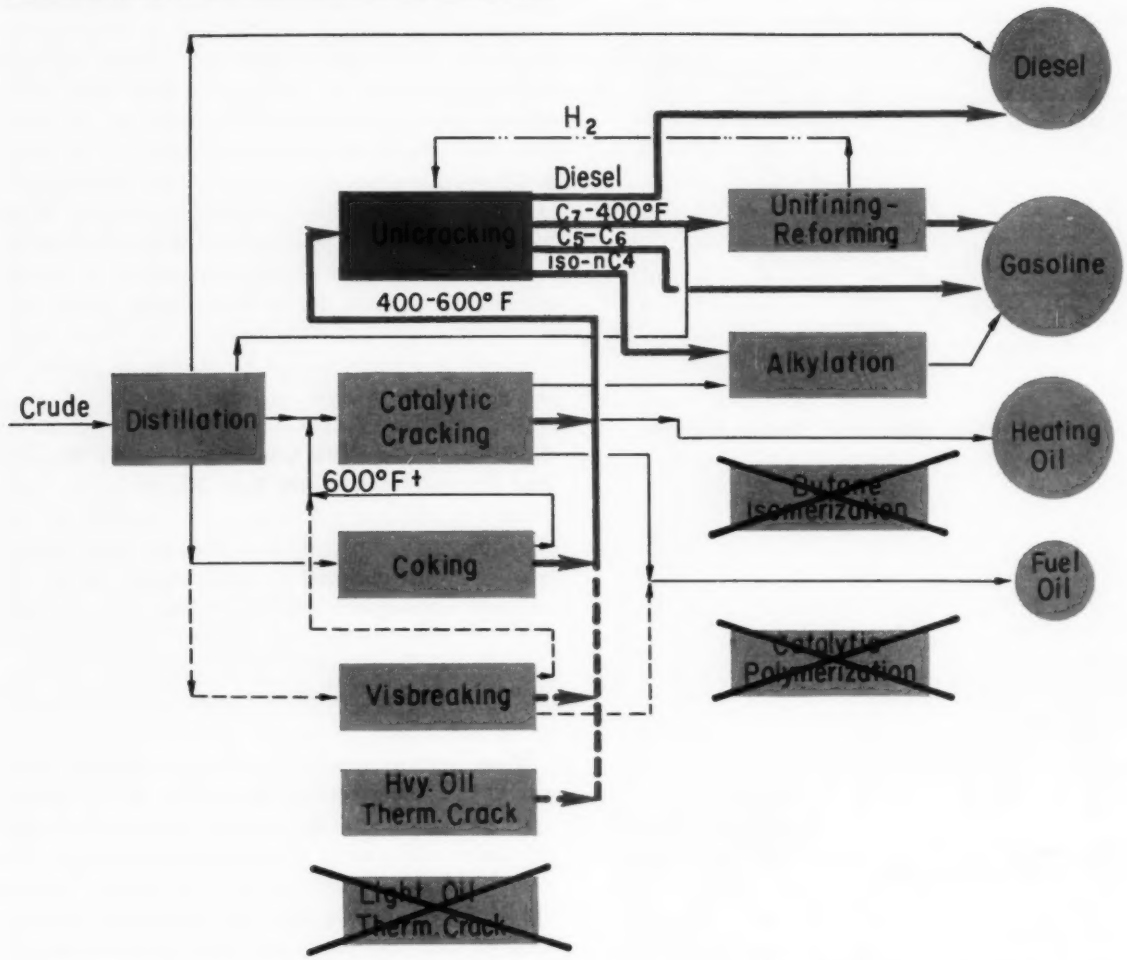


FIGURE 2—This simplified block diagram shows how Unicracking could fit into a typical refining scheme.

part of the light gas oils should be taken into account in economic studies.

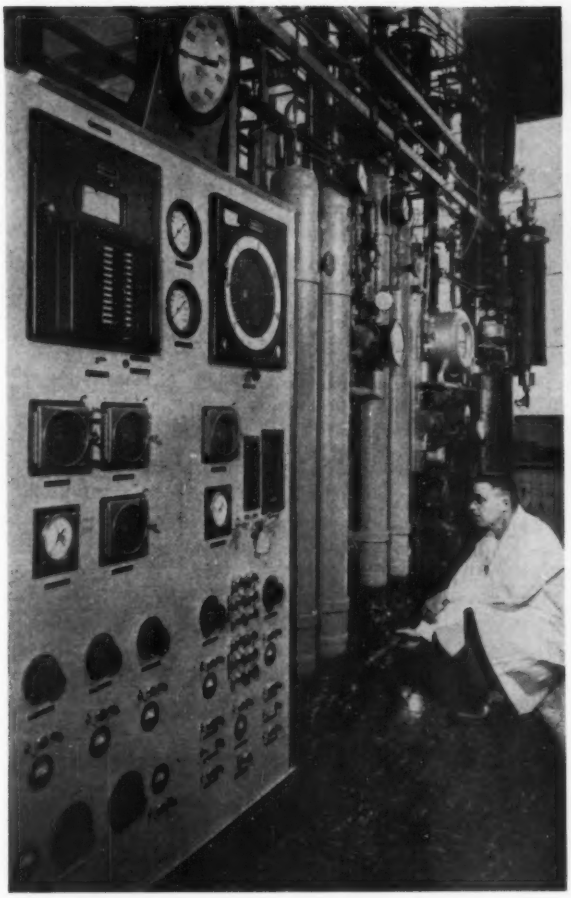
CAPITAL INVESTMENT AND OPERATING COSTS

The Union Oil and C F Braun Companies have prepared a definitive design and cost estimate of a 16,000 bpsd Unicracker. This work served to optimize both process and mechanical design and to establish basic cost data.

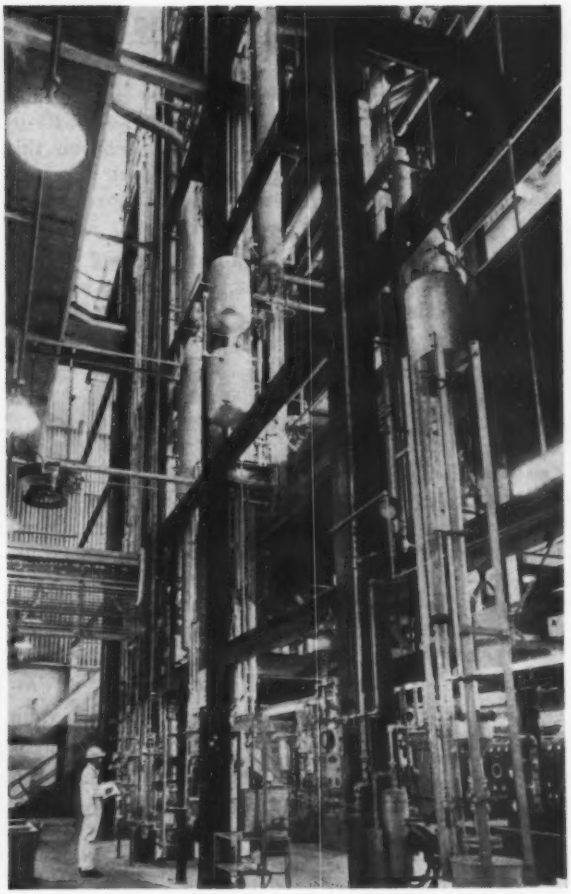
Capital and operating costs for typical 5,000, 10,000 and 15,000 bpsd units designed for conversion levels of 70 and 90 percent are shown in Table 7. These costs were estimated by C F Braun and are on the following basis:

- Feed boiling range is 400°-600°F by ASTM distallation.
- Feeds are highly aromatic (40-65 percent) stocks such as catalytic, thermal, and coker gas oils.
- Product fractionation is included to produce butanes, C_5-C_6 light gasoline, C_7-400° F gasoline, and the diesel fraction as shown on flowsheet.
- Hydrogen supply is from catalytic reformer at 80 percent concentration. The cost of this hydrogen and the cost of compression from reformer to Unicracker pressure are not included.
- All drives are electric.
- Process stream is generated on plot.
- Initial catalyst charge is included in capital investment.
- The estimated on-stream efficiency is 92 percent.

The total direct operating costs range from 23.9 cents/B for a 15,000 bpd plant at 70 percent conversion to 32.4 cents/B for a 5,000 bpd plant operating at 90 percent conversion. For cases where hydrogen supply is at higher purity, the capital and operating costs are reduced. For example, at 95 percent purity, from a hydrogen manufacturing plant, capital cost would be reduced by about 5 percent and operating costs would be reduced by about 1.7 cents per barrel. Generally, capital and operating costs will decrease as the end point of the feedstock decreases or as the



Small-scale experimental Unicracking unit.



Ten-bpd Unicracking pilot plant.

aromatic concentration of the feedstock decreases. The catalyst replacement cost is conservatively estimated at 5-6 cents/B and is based on a combination of accelerated catalyst coking, regeneration, activity testing, and pilot plant data on frequency of regeneration requirement.

REFINERY INTEGRATION

The economics of Unicracking for the refining situations investigated to date have been favorable from the standpoints of rate of return on investment and comparison with competitive schemes. The economics obviously depend on the objectives, existing refinery situations, product price structure and method of integration with existing facilities. Since these factors vary widely, each refiner's case must be considered separately.

Case I. The cracking of refractory, hydrogen-poor middle distillates is the application of most interest to refiners. The simplified block flow diagram in Figure 2 shows how Unicracking could fit into a typical refinery to accomplish this objective. This refinery could have alkylation, or catalytic polymerization, or both, and it could have coking or visbreaking of vacuum bottoms, or both. Many refineries also have two-coil thermal cracking to supplement the cat cracker.

In the proposed case, the refractory aromatic stocks from the catalytic cracker, coker, and thermal cracking units, boiling from 400°-600° F are fed to the Unicracker. A portion of these stocks also supplies the heating oil demand. The virgin gas oil, heavy coker and heavy visbreaker gas oils are fed to the existing cat cracker. Light oil thermal cracking is eliminated. The Unicracker and cat cracker complement each other through alkylation of the light olefins from the cat cracker with the isobutane from the Unicracker to maintain butane balance. For some size ratios of Unicracking to catalytic cracking, the need for butane isomerization or isobutane purchase is eliminated. An existing catalytic polymerization plant can usually be replaced by alkylation without installing an isomerization plant. The Unicracker C_5-C_6 fraction is blended directly to gasoline. The C_7-400° F Unicracker naphtha is reformed or in some cases may be blended directly to regular gasoline. The diesel fraction is blended directly.

The advantages of installing a Unicracker instead of another cat cracker for refractory stocks are:

- The Unicracker produces higher gasoline yield and no fuel oil. This allows greater reduction in crude oil rate, if constant gasoline volume is an objective.
- The quality of the gasoline pool is higher with lower sulfur and nitrogen content, lower olefin content, lower sensitivity and higher volatility. The gasoline

volatility may be further improved by also feeding the heavy catalytic gasoline (boiling 380-470° F) to the Unicracker where yields are excellent on this fraction. Since this fraction is not very high in octane and is too heavy to reform, Unicracking-reforming also increases the octane potential.

- From ten to fifty percent high-quality diesel may be produced from low-cetane stocks by simply lowering the conversion.
- The existing cat cracker efficiency (gasoline make over gas oil converted) is improved with the heavier feedstock resulting from adding the Unicracker. This is illustrated by the data shown in Table 6.

Case II. In a refinery study, where the feed is about 40 percent high-sulfur, low-gravity crude, and the remainder is low-sulfur crude, a refining route employing Unicracking of light coker, cat cracker, and high-sulfur, high-nitrogen virgin gas oils, combined with catalytic cracking of heavy gas oils gives a good payout. It also gives a better payout than the competitive route of cat cracking the full-range gas oils. Due to the high-sulfur and olefinic gas oils involved, considerable hydrogen production by methane reforming is required. With alkylation, there is no excess butane. No butane isomerization is required because of the isobutane produced in the Unicracker. Gasoline and diesel quality are considerably better than that from the competitive route. The diesel pool cetane is increased appreciably by blending gas oil bleed from the Unicracker. Bunker fuel oil production is also considerably lower.

Case III. In another refinery model study, excess reformer hydrogen is used to Unicrack light catalytic cycle oil currently being thermally cracked. The payout on a 4,000 bpd unit is excellent and fuel oil production is reduced appreciably. With this aromatic feedstock, the gasoline octane from the Unicracker is sufficient to allow direct blending in regular gasoline. The availability of excess reformer hydrogen naturally makes installation more attractive.

Original presentation before the Western Petroleum Refiners Association, San Antonio, Texas, March, 1960.

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When Metals Poison Cracking Catalyst

Here's an investigation of the effects of poisons on fluid catalytic cracking yields. See how the hydrogen producing factor can be used as a criterion for operating a commercial unit.

Earl C. Gossett
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Harvey, Ill.

NICKEL, VANADIUM and other metals contained in catalytic cracking feedstocks are deposited on the cracking catalyst adversely affecting its selectivity and activity. The pilot plant and bench scale work reported herein agree well with the known poisoning action of nickel and vanadium; namely, coke and gas yields increase with increasing metal levels.

Since the catalyst in the pilot and bench scale units was contaminated in a manner similar to that encountered commercially, it is felt the results developed here can be used quantitatively in those cases where the V_2O_5 to NiO ratio is in the range of 2.5 to 3.5. The hydrogen producing factor is then a reliable measure of the degree of metal poisoning. It can be used as a guide, by the fluid unit operator in selecting feedstocks and catalyst replacement rates.

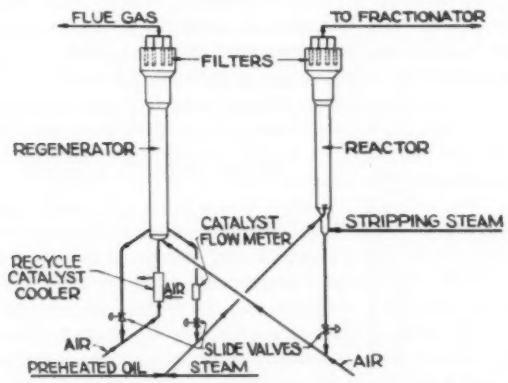

FIGURE 1—In addition to the work on the pilot plant fluid unit, catalyst testing was carried out on bench scale activity units.

Pilot Plant. The poisoning and product distribution runs were carried out on a nominal 3 bpd fluid catalytic cracking pilot plant. A schematic diagram of the plant is shown in Figure 1.

Preheated oil and dispersion steam enter the reactor through a riser and dispersion tee above the reactor grid. The purpose of the grid is to reduce catalyst backmixing from the stripping section directly below the reactor. In the poisoning runs, when processing an extremely heavy stock, oil was introduced at various times through an alternate entry near the top of the riser or directly into the reactor bed. Vapors exit from the top of the reactor through porous metal filters and pass through a fractionating system where light and heavy cycle oil are separated and weighed. Either or both cycle oil streams can be recycled although all work reported herein is from once through operation. Fractionator overhead is debutanized at nominally 120 psig to produce a C_5-360° F @ 90 percent point gasoline which is weighed and a total release gas stream, a composite sample of which is submitted for mass spectrometer analysis.

Spent catalyst leaves the reactor through a stripper, standpipe and slide valve and is carried by air to the regenerator. The regenerator temperature is controlled by recycling regenerated catalyst through a cooler. Orsat analyses of flue gases which leave the regenerator through porous metal filters are used to calculate coke yields. Catalyst circulation rate is measured by a flow meter located in the regenerator standpipe. This instrument, operating on the principle of a Thomas meter, gives a nearly continuous record of the rate of catalyst flow.

Bench Scale Units. In addition to the work on the pilot plant fluid unit, catalyst testing was carried out on bench scale activity units. Standard test conditions on these fixed bed downflow units which test the catalyst in powder form are shown in Table 1.

TABLE 1—Test Conditions—Bench Scale Activity Test

Temperature, °F	900
Pressure	Atmospheric
Time on Stream, Min	30
Feed Rate, cc/Hour	100
Feed Charged Per Test, cc	50
Weight Hourly Space Velocity, Wo/Wc/Hour	2.0
Catalyst to Oil Weight Ratio	1.0
Catalyst Form	Powder
Condenser Temperature, °F	60
Charge Stock	East Texas Gas Oil
Gravity, °API	34.0
Distillation, °F	
IBP	500
10 Percent	540
50 Percent	590
90 Percent	660
EP	700

The liquid product is charged to a small fractionating column to determine the weight percent of 410° F EP gasoline. Coke is determined by regenerating the catalyst in place. The relative activity, coke and gas factors can be calculated from the weight percent conversion, coke and gas yields. Relative activity is an inverse ratio of the

What Metal Poisoning Does To Cat Cracking Yields . . .

To obtain additional feedstock for catalytic cracking, most fluid unit operators would like to recover more gas oil from crude. The additional gas oil can be recovered by heavy fuel reduction processes such as deep vacuum flashing, visbreaking, coking and solvent extraction but its relatively high metal content is a controlling factor in determining the economics of such processing. In addition to providing increased quantities of feedstock, this approach also upgrades material which would otherwise be disposed of as heavy fuel.

It is well known that nickel, vanadium, iron, and copper compounds contained in catalytic cracking feedstocks are deposited on the catalyst during the cracking operation. As a result both the activity and the selectivity of the catalyst are adversely affected if metals are allowed to accumulate.[1,2,3]

Poorer selectivity with increasing metals level is characterized by higher yields of coke and gas, particularly hydrogen, and a lower yield of gasoline. Since many fluid units are limited by coke burning or gas handling facilities, increased coke or gas yields require a reduction in conversion or throughput to stay within the unit capacity.

An alternative to letting catalyst metals level increase and activity decrease is to purge the metals by raising catalyst addition rates. Either approach, letting metals level increase or increasing catalyst addition rates, must be balanced against product value and operating costs to determine the most economic way of operating. The optimum metal level at which to operate any fluid unit will be a function of many factors including feedstock metal content, type and cost of catalyst, over-all refinery balance, etc., and can be determined only by a comprehensive study of the refinery's operations.

Several investigators have reported on the effect of metals on catalyst activity and selectivity, but in most cases the metals have been deposited on steam deactivated catalysts by artificial means such as impregnation[4] or by adding oil soluble compounds to the feedstocks before processing.[5] It has been our experience that poisoning by these methods is normally more severe than that encountered in commercial operations. It is also difficult to prepare sufficient quantities of poisoned catalysts, particularly by impregnation, for pilot plant testing. As a result, most reported data on metal poisoning have been obtained on bench scale equipment.

In an attempt to more closely approximate commercial poisoning results, metals, primarily nickel and vanadium, were deposited on equilibrium clay and synthetic catalysts by processing a high metal content, heavy feedstock in a pilot plant fluid unit. Product distribution data were then obtained on both catalysts at various metal levels by cracking a conventional fluid feedstock. Bench scale activity data were also obtained on these catalysts. The results, under certain conditions, can be used to evaluate heavy fuel reduction processes and to determine optimum catalyst metals level at which to operate.

About the Author

Earl C. Gossett is a project engineer in the Process Division of the Sinclair Research Laboratories, Inc., Harvey, Ill. There he plans programs and evaluates results from laboratory and pilot plant studies of catalytic cracking and related processes. Gossett started with the Sinclair labs in 1948 after receiving a B.S. degree in chemical engineering from Michigan State University.

amount of catalyst that is required in the reaction bed of a unit to give the same conversion as a standard virgin silica-alumina catalyst at the same holding time and operating conditions. A relative activity of 100 was arbitrarily assigned to the standard catalyst.

The gas factor, also determined on these units, is a ratio of the volumetric gas yield on the test catalyst and the yield on a reference catalyst at the test catalyst conversion. In this case the gas referred to is from a 60° F flash of the reactor effluent. The coke factor is a similar ratio between weight percent coke yields.

Poisoning. In both the clay and synthetic catalyst programs approximately 190 pounds of equilibrium catalyst, obtained from commercial operations, were charged to the pilot plant fluid unit. Varying quantities of heavy feedstocks containing as much as 50 ppm NiO were processed over the equilibrium catalysts until the desired metal levels were reached. Since the original deposition of metals on the equilibrium catalysts occurred in commercial units and subsequent poisoning in the pilot plant used feedstocks containing natural occurring metals, there is a fixed relationship between the vanadium oxide and nickel oxide contents of the catalysts. For most of the work reported here the ratio of V_2O_5 to NiO on the catalyst varied between 2.5 and 3.5.

Surface areas of the catalysts were held relatively constant throughout the programs by adding approximately 5 pounds per barrel of feed of equilibrium catalyst while discarding a like amount.

Product Distribution. At each metal level tests were made at varying conversions to determine product distribution. For ease of presentation, the metal levels at which data were obtained are referred to only in terms of NiO although it is recognized that other metals on the catalyst such as vanadium and iron also contribute to poisoning although to a lesser extent than nickel.

TABLE 2—Feedstock Inspections

Predominately Mid-Continent Gas Oil.	
Gravity, °API	27.1
Vacuum Distillation, °F	
IBP	444
10 Percent	636
50 Percent	761
90 Percent	943
Sulfur, Weight Percent	0.58
Aniline Point, °F	189.0
Kinematic Viscosity, cs/122° F.	18.78
Refractive Index n_D^{20}	1.4960
Carbon Residue (Ramsbottom), Weight Percent	0.500
NiO, PPM	0.48
V_2O_5, PPM	1.69

Feedstock for these tests was a commercial fluid unit feed consisting predominately of Mid-Continent gas oils from atmospheric distillation, vacuum flashing, and deasphalting units. Typical inspections of the feedstock are shown in Table 2. Other feedstocks containing different quantities of sulfur, chlorine, and other trace impurities may react differently in magnitude to metals but it is felt that qualitatively the results obtained here are typical.

Operation of the pilot plant fluid unit was at 960° F reactor temperature for the clay catalyst program and 910° F for the synthetic catalyst. Catalyst-oil ratio was held at 8 to 1 for all tests. Stripping steam was maintained at 16 weight percent on feed in both programs but dispersion steam averaged 14 weight percent on feed in the clay catalyst program and 4 weight percent in the program on synthetic catalyst.

In addition to product distribution tests in the pilot plant, the catalyst at each metals level was evaluated by activity testing on the bench scale units.

The catalyst for this study was an equilibrium catalyst obtained from a commercial fluid unit. It was a mixture of approximately 75 percent montmorillonite and 25 percent kaolinite clays. Average inspections of the catalyst during the tests at the 250 ppm NiO level are shown in Table 3. This catalyst was further poisoned to 850 and 1,500 ppm NiO in the pilot plant as discussed previously.

As shown in Figure 2, coke yield at a given conversion increases as metals accumulate on the catalyst. This increase in coke comes predominately at the expense of depropanized gasoline. Figures 3 and 4 show the decrease in yields of debutanized gasoline and total butanes plus butylenes at a given conversion which accompanies an increase in metals level. Although there is little change in the weight percent yield of propane and lighter, there is a significant increase in the volume of hydrogen produced. This is reflected by the hydrogen producing factor, a ratio of the mol.% hydrogen to the mol.% methane, ethane, and ethylene, shown in Figure 5. This factor, because of its high sensitivity to changing metal levels, gives the fluid unit operator a reliable criterion by which to adjust his catalyst makeup rates or select his feedstocks.

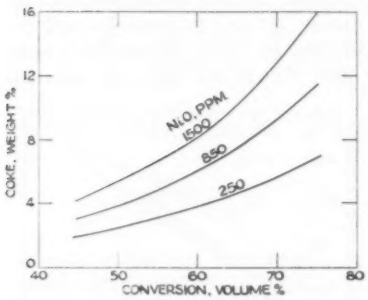

FIGURE 2—Coke yield at a given conversion increases as metals accumulate on the catalyst.

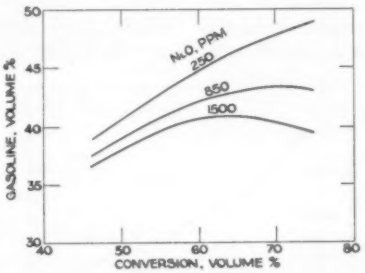

FIGURE 3—Yields of debutanized gasoline decrease with increases in metals level at given conversion.

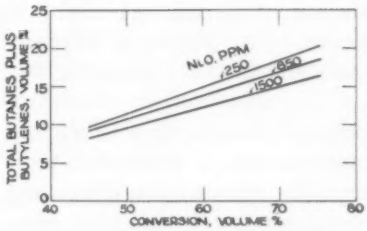

FIGURE 4—Metals accumulation also causes total butanes plus butylenes to be higher.

RESULTS—PILOT PLANT

Clay Catalyst. The poisoning study on clay catalyst was conducted at nominal NiO levels of 250, 850 and 1,500 ppm. These relatively high levels, particularly the latter two, were selected so that the results could be used in evaluating heavy fuel reduction processes such as visbreaking, deasphalting and coking which often produce gas oils high in nickel and vanadium content. With the lower cost clay catalyst, addition rates can often be adjusted to process contaminated stocks at moderate metal levels. However, even these catalyst costs can become excessive if the catalyst metal level is held too low with relationship to the feedstock metal content. It is possible with results obtained from this study to determine the most economical metal level at which to operate for a feedstock similar to the one used in this program.

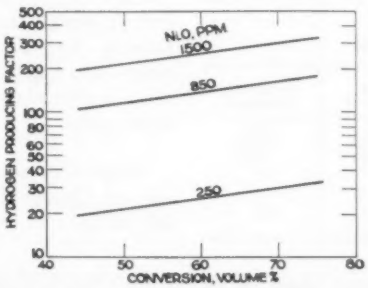

FIGURE 5—The hydrogen producing factor reflects changes in metals level.

Metal poisoning had no appreciable effect on gasoline octanes.

Synthetic Catalyst. To more fully explore the effect of metals at low levels of contamination, a similar study was carried out using synthetic catalyst at nominal NiO levels of 70, 450 and 800 ppm. The base equilibrium catalyst was obtained from a commercial unit processing a relatively low metal content feed. Average catalyst inspections during tests at the 70 ppm NiO level also are shown in Table 3. Added poisoning, as discussed previously, was carried out in the pilot plant.

Results on the synthetic catalyst, as shown in Table 4, were directionally the same as those on natural cata-

lyst illustrated earlier in Figures 2-5. Coke and hydrogen yields increased whereas gasoline, and total butanes plus butylenes decreased at constant conversion with increasing metal levels. Hydrogen producing factor again appears to be a good criterion of the degree of poisoning.

A limited study on a commercially poisoned low alumina synthetic catalyst was made to compare the poisoning effect of metals deposited during commercial operations with the effect of metals deposited in the pilot plant studies. Product distribution runs on the pilot plant fluid unit were made using the same commercial fluid cracking feedstock and the same operating conditions as used in the synthetic catalyst study. Although the poisoning effects of metals deposited in the commercial operation was slightly less pronounced, particularly with respect to hydrogen make and hydrogen producing factor, the results on the pilot plant poisoned catalysts are a satisfactory approximation of results on a commercially poisoned catalyst and should give valid conclusions when used to evaluate the effect of metal contamination.

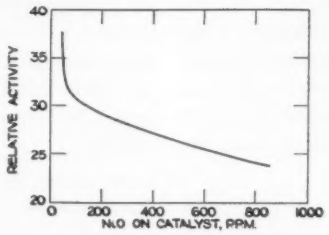

FIGURE 6—The relative activity of the synthetic catalyst declined with increasing metals level.

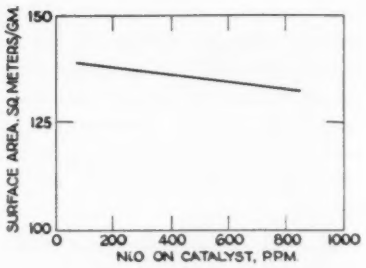

FIGURE 7—Surface area has been shown to be little affected by metal poisoning.

RESULTS—BENCH SCALE

Catalysts from the pilot plant poisoning programs were tested on bench scale activity testing units for activity and gas and coke producing factors. Surface areas, a measure of catalyst deactivation, were also obtained on the catalysts.

Although the relative activity of the synthetic catalyst declined with increasing metals level as illustrated in Figure 6, the surface area, shown in Figure 7, was maintained reasonably well. Surface area, which is greatly affected by deactivating agents such as temperture and steam,[6,7] has been shown in our laboratories and by others[8] to be little affected by metal poisoning. It may be concluded then that the lower activities resulted mainly from increased metals on the catalyst rather than from normal catalyst aging. Figures 8 and 9 show the increase in gas and coke producing factors and the decrease in gas gravity with increasing metal levels for the synthetic catalyst.

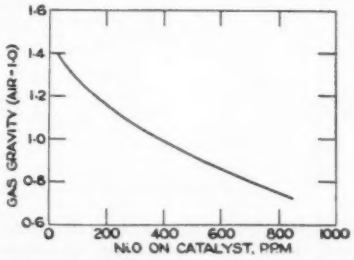

FIGURE 8—Here are gas and coke producing factors for the synthetic catalyst.

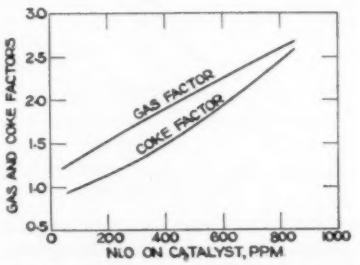

FIGURE 9—A lighter gas is produced as the metals level increases.

Similar activity, area, gas and coke producing factors, and gas gravity results were obtained on the clay catalyst. Although these bench scale results represent qualitatively the effect of metal poisoning, it is felt that quantitative predictions must come from a program such as that run on the pilot plant or from commercial experience.

TABLE 3—Catalyst Inspections

	Clay Catalyst	Synthetic Catalyst
Relative Activity	30.4	32.2
Gas Factor	1.07	1.28
Coke Factor	0.98	0.96
Surface Area, Sq.M./Gm.	119	138
Metals, PPM		
NiO	250	70
V_2O_5	650	250

TABLE 4—Effect of Metals on Fluid Cracking Yields at 60 Volume % Conversion (Low Alumina Synthetic Catalyst)

NiO on Catalyst, PPM	70	450	800
Reactor Temperature, °F	910	910	910
Combined Feed Ratio	1.0	1.0	1.0
Isobutane, Volume Percent	6.7	5.5	3.8
Butylenes, Volume Percent	9.7	9.2	9.2
Normal Butane, Volume Percent	1.1	1.1	1.1
Total Butanes Plus Butylenes, Volume Percent	(17.5)	(15.8)	(14.1)
Gasoline (C_5-360° F @ 90%), Volume Percent	41.0	39.4	35.5
Cycle Oil, Volume Percent	40.0	40.0	40.0
Dry Gas, C_3 and Lighter, Weight Percent	8.9	8.9	8.2
Coke (10% Hydrogen), Weight Percent	4.6	7.0	12.1
Hydrogen Std. Cu. Ft./Bbl. of Feed	30	218	490
Hydrogen Producing Factor	24	159	358

Original presentation was before the American Institute of Chemical Engineers, San Francisco, December 6-9, 1959.

ACKNOWLEDGMENT

The work reported here is the result of the effort of many people without whose help it could not have been completed. The author would like to express his appreciation to all of them and to the Sinclair Research Laboratories, Inc. for permission to publish these results.

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Applied Hydrocarbon Thermodynamics

Part 18: Vapor-Liquid Equilibrium Fundamentals

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PROCESS CALCULATIONS for coexisting vapor-liquid mixtures are made by using the convenient vapor-liquid K value, sometimes called "the equilibrium phase distribution ratio," which is defined

$$K_i = \frac{y_i}{x_i} = \frac{\text{mol fraction of component "i" in vapor phase}}{\text{mol fraction of component "i" in liquid phase}} \qquad (18.1)$$

In terms of mol quantities the vapor-liquid K value is is

$$K_i = \frac{v_i}{l_i} \frac{\Sigma l_i}{\Sigma v_i} \qquad (18.2)$$

The K values for components of a mixture can be found experimentally by finding the composition of the vapor and liquid from an apparatus designed and operated to achieve an equilibrium separation of the equilibrium vapor and liquid phases.

Experimental measurements are time consuming and costly so theoretical and empirical methods are also used to predict and correlate K values, thus making experimental observations go further. These theoretical and empirical methods utilize thermodynamics, as will be demonstrated after showing the relationships between K value and fugacity, pressure and vapor pressure.

Fugacity K Values. Fugacity was devised about 35 years ago and proposed as a more convenient function for use in making equilibrium calculations. Fugacities, which have the units of pressure, are used instead of chemical potential or free energy to express the criteria for equilibria which are:

$$T^V = T^L$$
$$P^V = P^L$$
$$\bar{f}_i^V = \bar{f}_i^L$$

where: the superscripts V and L designate vapor and liquid while the subscripts "i" refers to any component. The bar above f designates the value of the fugacity in a mixture.

In other words: In addition to equal temperatures and pressures for each phase the fugacities of each component must be the same in both phases. This fugacity criteria is equivalent to equal chemical potential for each component in both phases. This will be discussed more later. Expressions for K_i are formulated in terms of this fugacity equality. Introduction of fugacities into the equilibrium K value definition of Equation 18.1 gives

$$K_i = \frac{\bar{f}_i^L / x_i}{\bar{f}_i^V / y_i} \qquad (18.3)$$

Multiplying the denominator by P/P (system pressures) gives

$$K_i = \frac{\bar{f}_i^L / x_i}{\bar{f}_i^V / P y_i} \frac{1}{P} \qquad (18.4)$$

This is the K-value relationship that Benedict et al[1] used in developing the Polyco or Kellogg PTC K charts from the B-W-R equation of state. K values by this equation are functions of temperature, pressure and composition of both phases.

Multiplying the numerator by P_i°/P_i° (vapor pressures) gives

$$K_i = \frac{(\bar{f}_i^L / P_i^\circ x_i)}{(\bar{f}_i^V / P y_i)} \frac{P_i^\circ}{P} \qquad (18.5)$$

This is the K value relationship that Edmister and Ruby[2] used in recorrelating the Kellogg K charts.

It will be noted that the last term of Equation 18.5 namely the ratio of vapor pressure to total pressure, P_i°/P, is the Raoult's Law K value for ideal solution and perfect gas behavior. The ratio of the two fugacity coefficients preceding P_i°/P is the correction for deviation from Raoult's Law. These fugacity coefficients are functions of temperature, pressure and composition of the phases.

Another fugacity expression for the vapor-liquid K value was evaluated recently by Prausnitz, Edmister and Chao.[3] Multiplying the numerator of Equation 18.4 by f_i^L/f_i^L gives

$$K_i = \frac{\bar{f}_i^L / f_i^L x_i}{\bar{f}_i^V / P y_i} \left(\frac{f}{P}\right)_i^L = \frac{\gamma_i^L \nu_i}{\phi_i} \qquad (18.6)$$

Where: $\gamma_i^L = (\bar{f}/fx)_i^L =$ activity coefficient of component "i" in liquid mixture

$\nu_i = (f/P)_i^L =$ fugacity coefficient of component "i" as pure liquid

$\phi_i = (\bar{f}/Py)_i^V =$ fugacity coefficient of component "i" in vapor mixture

If properly evaluated, fugacities cover deviations from the perfect gas law and from ideal solutions. For ideal solutions, where Amagats Law of additive volumes holds the fugacities $\bar{f}_i^L$ and $\bar{f}_i^V$ can be found by the following relations, which will be derived later and identified as the Lewis and Randall Fugacity Rule:

$$\bar{f}_i^L = x_i f_i^L \text{ and } \bar{f}_i^V = y_i f_i^V$$

Combining these ideal mixture fugacity relationships

with Equation 18.3 gives the following for the ideal K value

$$K_{Ideal} = \frac{f_i^L}{f_i^V} \qquad (18.7)$$

Where: f_i^L and f_i^V are the fugacities of component "i" in the pure liquid or vapor states at the system temperature and pressure.

K_{Ideal} is a function of system temperature and pressure only for each component and independent of composition.

Equation 18.7 is the basic relationship evaluated in preparing the well-known MIT K charts. For convenience in evaluating the fugacities, pressures and vapor pressures were introduced by multiplying the numerator by (P_i°/P_i°) and the denominator by (P/P), giving

$$K_{Ideal} = \left(\frac{f_i^L/P_i^\circ}{f_i^V/P}\right)\left(\frac{P_i^\circ}{P}\right) = \left(\frac{f_i^L/P_i^\circ}{f_i^V/P}\right)K_{Raoults} \qquad (18.8)$$

Equation 18.8 gives the relationship between K_{Ideal} and K_{Raoult} for ideal solutions.

An expression giving the K value in terms of K_{Ideal} and activity coefficient correction factors is obtained from Equation 18.3 by multiplying the numerator by (f_i^L/f_i^L), multiplying the denominator by (f_i^V/f_i^V) and then combining with Equation 18.7, giving

$$K_i = \frac{\bar{f}_i^L/x_i}{\bar{f}_i^V/y_i} = \frac{(\bar{f}/xf)_i^L}{(\bar{f}/yf)_i^V}\,\frac{f_i^L}{f_i^V} = \frac{\gamma_i^L}{\gamma_i^V}K_{Ideal} \qquad (18.9)$$

Theoretically the fugacity and activity coefficients in the above equations can be evaluated from pressure-volume-temperature-composition (PVTC) data. For both liquid and vapor mixtures, hypothetical pure component states, requiring empirical treatment, are encountered.

For example: A light gaseous component might be dissolved in a liquid mixture at temperature and pressure conditions under which the component in question could not exist as a pure liquid. In this case a hypothetical pure liquid state must be assumed in calculating the pure liquid fugacity.

A similar situation could exist for the vapor phase, where a heavy component might be in the vapor mixture at conditions under which the component in question could not exist as a pure vapor. In this case a hypothetical pure vapor state must also be assumed in calculating the pure vapor fugacity.

Thermodynamics of Phase Equilibria. A discussion of the thermodynamics of vapor-liquid phase equilibria will provide a theoretical basis for the above fugacity relationships and lead to methods for computing the fugacity coefficients from PVTC data.

A thermodynamic property called "chemical potential" and given the symbol μ relates the effect of composition on the other thermodynamic potentials.

For systems of constant composition

$$dE = TdS - PdV \qquad (18.10)$$

$$dH = TdS + VdP \qquad (18.11)$$

$$dA = -SdT - PdV \qquad (18.12)$$

$$dF = -SdT + VdP \qquad (18.13)$$

For mixtures, these thermodynamic potentials (E, H, A, and F) are functions of composition also. Defining enthalpy as a function of S, P, and N for systems of changing composition.

$$dH = \left(\frac{\partial H}{\partial S}\right)_{P,N_i} dS + \left(\frac{\partial H}{\partial P}\right)_{S,N_i} dP + \left(\frac{\partial H}{\partial N_A}\right)_{P,S} dN_A + \ldots + \left(\frac{\partial H}{\partial N_N}\right)_{P,S} dN_N \qquad (18.14)$$

From Equation 18.11

$$\left(\frac{\partial H}{\partial S}\right)_{P,N_i} = T, \text{ and } \left(\frac{\partial H}{\partial P}\right)_{S,N_i} = V$$

Substituting in Equation 18.14 gives

$$dH = TdS + VdP + \left(\frac{\partial H}{\partial N_A}\right)_{P,S} dN_A + \ldots + \left(\frac{\partial H}{\partial N_N}\right)_{P,S} dN_N \qquad (18.15)$$

In like manner

$$dE = TdS - PdV + \left(\frac{\partial E}{\partial N_A}\right)_{S,V} dN_A + \ldots + \left(\frac{\partial E}{\partial N_N}\right)_{S,V} dN_N \qquad (18.16)$$

$$dF = -SdT + VdP + \left(\frac{\partial F}{\partial N_A}\right)_{P,T} dN_A + \ldots + \left(\frac{\partial F}{\partial N_N}\right)_{P,T} dN_N \qquad (18.17)$$

An analogous equation can be written for the work function A but this will not be required.

By definition $A = E - TS$ and $F = A + PV$ from which
$F = E - TS + PV$

Differentiating

$$dF = dE - TdS - SdT + PdV + VdP \qquad (18.18)$$

Combining Equations 18.16, 18.17, and 18.18 and defining the partial quantities $\bar{E}_i$ and $\bar{F}_i$ gives

$$\bar{E}_i = \left(\frac{\partial E}{\partial N_i}\right)_{S,V,N_j} = \left(\frac{\partial F}{\partial N_i}\right)_{T,P,N_j} = \bar{F}_i \qquad (18.19)$$

Doing the same for enthalpy, starting with the definition
$F = H - TS$

Differentiating, rearranging and subtracting VdP from both sides gives

$$dF + SdT - VdP = dH - TdS - VdP \qquad (18.20)$$

Combining Equations 18.15 and 18.17 and 18.20 with the definitions for $\bar{F}_i$ and $\bar{H}_i$ gives

$$\bar{H}_i = \left(\frac{\partial H}{\partial N_i}\right)_{P,S,N_j} = \left(\frac{\partial F}{\partial N_i}\right)_{P,T,N_j} = \bar{F}_i \qquad (18.21)$$

An examination of Equations 18.19 and 18.21 shows that the partial quantities of energy, enthalpy and free energy are equal. These are defined as the "chemical potential", μ_i, where

$$\mu_i = \left(\frac{\partial E}{\partial N_i}\right)_{V,S,N} = \left(\frac{\partial H}{\partial N_i}\right)_{S,P,N_j} = \left(\frac{\partial A}{\partial N_i}\right)_{T,V,N_j} = \left(\frac{\partial F}{\partial N_i}\right)_{T,P,N_j} \qquad (18.22)$$

or

$$\mu_i = \bar{E}_i = \bar{H}_i = \bar{A}_i = \bar{F}_i \qquad (18.23)$$

In terms of the chemical potential the differential equations for the four thermodynamic potentials, E, H, A, and F become

$$dE = TdS - PdV + \mu_i dN_i \qquad (18.24)$$

$$dH = TdS + VdP + \mu_i dN_i \qquad (18.25)$$

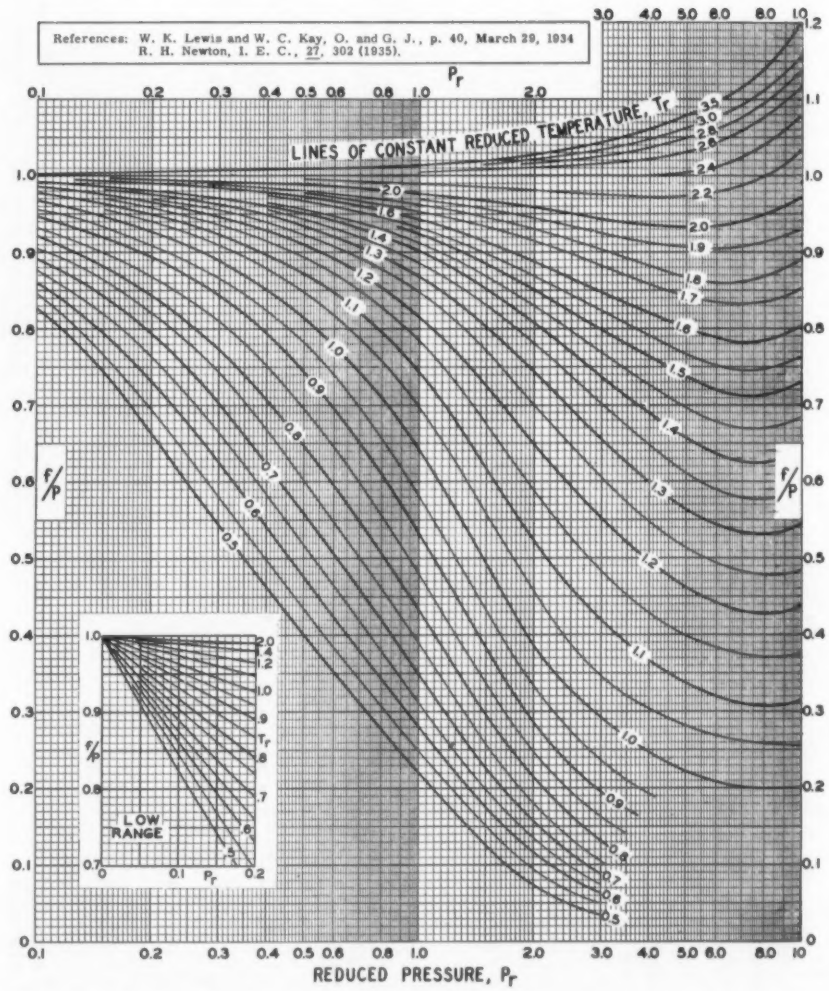

References: W. K. Lewis and W. C. Kay, O. and G. J., p. 40, March 29, 1934
R. H. Newton, I. E. C., 27, 302 (1935).
LINES OF CONSTANT REDUCED TEMPERATURE, Tr
f/p
LOW RANGE
REDUCED PRESSURE, Pr

FIGURE 18.1—Generalized activity coefficients for pure vapors.

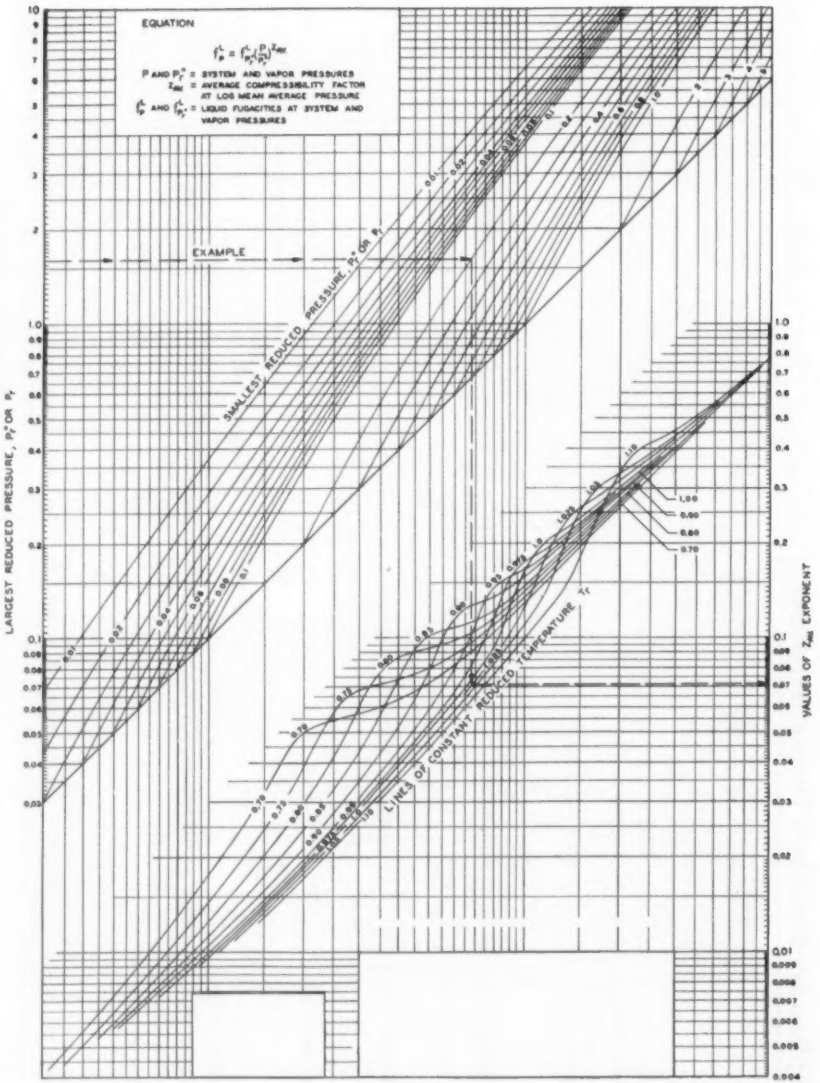

EQUATION
EXAMPLE
SMALLEST REDUCED PRESSURE P2* OR P1
LARGEST REDUCED PRESSURE, P2* OR P1
LINES OF CONSTANT REDUCED TEMPERATURE Tr
VALUES OF Zav EXPONENT

FIGURE 18.2—Exponent for pressure correction to the liquid fugacity of hydrocarbons (right).

$$dA = -SdT - PdV + \mu_i dN_i \quad (18.26)$$

$$dF = -SdT + VdP + \mu_i dN_i \quad (18.27)$$

Any one of these equations can be used to obtain the Gibbs-Duhem Equation. Apply to E, which is homogeneous in S, V, and N.

Integrating Equation 18.24 at constant composition

$$E = TS - PV + \Sigma\mu_i N_i \quad (18.28)$$

Differentiating with no restrictions

$$dE = TdS + SdT - PdV - VdP + \Sigma N_i d\mu_i + \Sigma\mu_i dN_i \quad (18.29)$$

Subtract Equation 18.24 from Equation 18.29 gives

$$VdP - SdT = \Sigma N_i d\mu_i \quad (18.30)$$

at constant P and T

$$\Sigma N_i d\mu_i = 0 \quad (18.31)$$

Equations 18.30 and 18.31 are forms of the Gibbs-Duhem Equation.

For a given pressure and temperature the free energy, F, is a minimum at equilibrium. One criteria of equilibria can be shown to be

$$\mu_i^V = \mu_i^L$$

where: the superscripts designate vapor and liquid phases and the subscript "i" on μ refers to each component.

Chemical potential was originated by J. Willard Gibbs about 70 years ago in his famous work on equilibria. While fundamental, chemical potential is not very convenient for use in solving problems. This equality of chemical potentials is equivalent to an equality of fugacities.

Fugacity Relations. From Equation 18.13 for an isothermal process

$$\left(\frac{\partial F}{\partial P}\right)_T = V \quad (18.32)$$

Integrating gives

$$F_2 - F_1 = \int_1^2 VdP \quad (18.33)$$

For a perfect gas, where V = RT/P, Equation 18.33 becomes

$$F_2 - F_1 = RT \ln \frac{P_2}{P_1} \quad (18.34)$$

Fugacity is defined as the replacement for pressure to make this expression applicable to real gases, i.e.

$$F_2 - F_1 = RT \ln \frac{f_2}{f_1} \quad (18.35)$$

The fugacity of a component in a mixture is defined by a similar expression

$$\bar{F}_{i_2} - \bar{F}_{i_1} = RT \ln \frac{\bar{f}_{i_2}}{\bar{f}_{i_1}} \quad (18.36)$$

or

$$\mu_{i_2} - \mu_{i_1} = RT \ln \frac{\bar{f}_{i_2}}{\bar{f}_{i_1}} \quad (18.37)$$

where: the bar above indicates the value of the property in a mixture, the subscript "i" designates any component and the subscripts 1 and 2 indicate any two points on an isotherm.

In differential form the preceding definition of fugacity of a component in a mixture is

$$d\mu_i = RTd \ln \bar{f}_i \quad (18.38)$$

Activity is defined as a fugacity ratio, i.e.

$$a_i = f_i/f_i^\circ \quad (18.39)$$

where: f_i = fugacity of pure "i" at temperature and pressure of interest.

f_i° = fugacity of pure "i" at temperature of interest and a standard state pressure P°.

Any standard state reference pressure can be chosen as long as there is a method of calculating up to it and away from it. It is customary to choose the ideal gas state for unit fugacity.

For a mixture the activity is

$$a_i = \frac{\bar{f}_i}{f_i^\circ} \quad (18.40)$$

From these definitions of activity Equations 18.35 and 18.37 become

$$F_i - F_i^\circ = RT \ln \frac{f_i}{f_i^\circ} = RT \ln a_i \quad (18.41)$$

$$\mu_i - \mu_i^\circ = RT \ln \frac{\bar{f}_i}{f_i^\circ} = RT \ln \bar{a}_i \quad (18.42)$$

In the standard state is the pure component, $\mu_i^\circ = F_i^\circ$.

Fugacity—PVT Data Equations. Combining Equations 18.33 and 18.35 gives

$$RT \ln \frac{f_2}{f_1} = \int_1^2 VdP \quad (18.43)$$

In differential form

$$\left(\frac{\partial \ln f}{\partial P}\right)_T = \frac{V}{RT} \quad (18.44)$$

Replacing V in Equation 18.43 by the difference between the ideal gas and the residual gas volumes, i.e. $V = RT/P - \alpha$, gives

$$RT \ln \frac{f_2}{f_1} = RT \ln \frac{P_2}{P_1} - \int_1^2 \alpha dp \quad (18.45)$$

Rearranging and letting $P_1 \to 0$

where:
$$\lim_{P_1 \to 0} \frac{f}{P} = 1$$

gives

$$RT \ln \frac{f}{P} = -\int_0^P \alpha dp \quad (18.46)$$

Equation 18.46 is the fugacity coefficient for a pure component. A similar expression for the component of

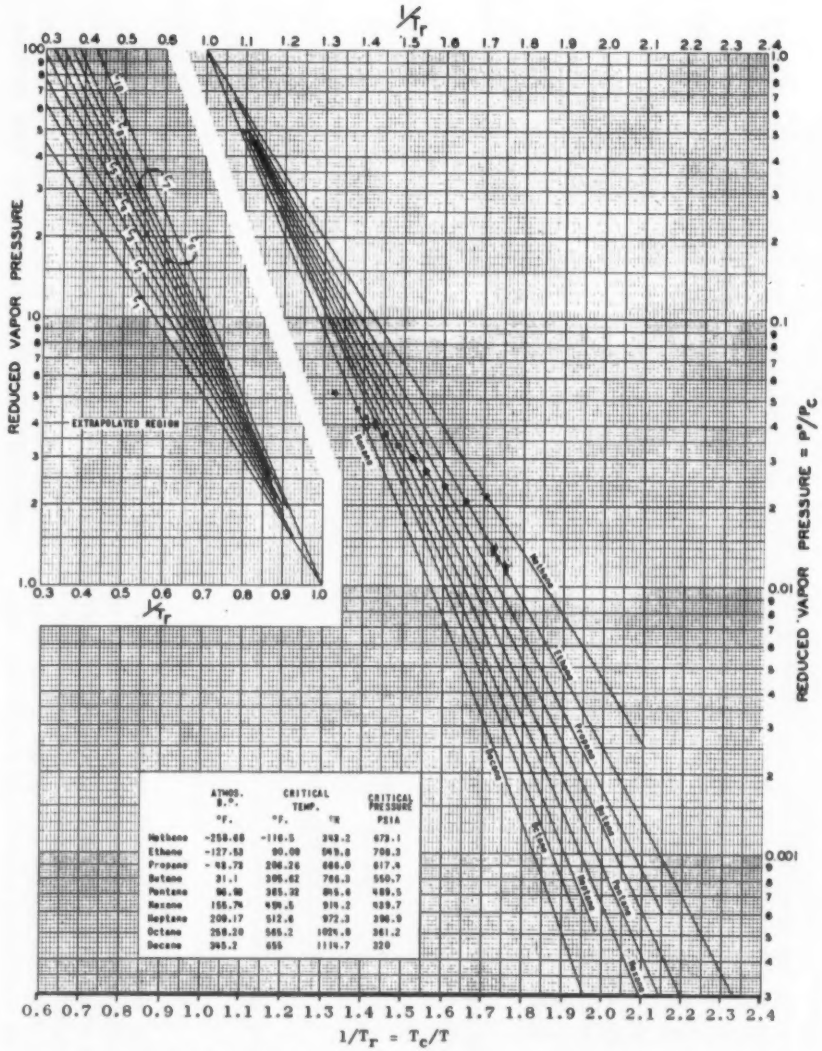


FIGURE 18.3—Reduced vapor pressures of normal paraffins.

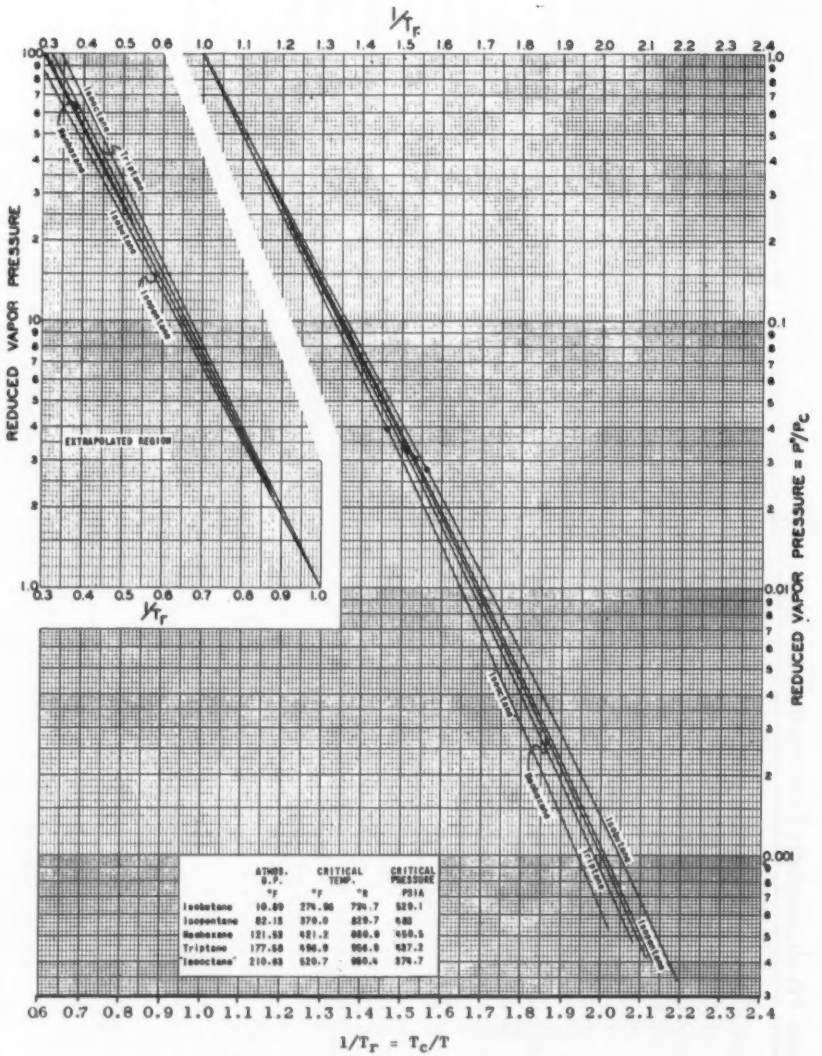


FIGURE 18.4—Reduced vapor pressures of isoparaffins.

a mixture is developed from Equation 18.42 by a more lengthy procedure.

Differentiating Equation 18.42 at constant temperature and composition

$$\left(\frac{\partial \mu_i}{\partial P}\right)_{T,N_j} = RT\left(\frac{\partial \ln \bar{f}_i}{\partial P}\right)_{T,N_j} \quad (18.47)$$

The left hand term may be replaced by $\bar{V}_i$, which equality is developed by differentiating Equation 18.32 with respect to composition, as follows:

$$\frac{\partial\left(\frac{\partial F}{\partial P}\right)}{\partial N_i} = \frac{\partial V}{\partial N_i}$$

changing the order of differentiation of the left side

$$\frac{\partial\left(\frac{\partial F}{\partial N_i}\right)}{\partial P} = \frac{\partial V}{\partial N_i},$$

from which

$$\left(\frac{\partial \bar{F}_i}{\partial P}\right)_{T,N_j} = \bar{V}_i = \left(\frac{\partial \mu_i}{\partial P}\right)_{T,N_j} \quad (18.48)$$

Combining Equations 18.47 and 18.48 gives

$$\left(\frac{\partial \ln \bar{f}_i}{\partial P}\right)_{T,N_j} = \frac{\bar{V}}{RT} \quad (18.49)$$

Equation 18.49 is analogous to Equation 18.44 for a pure component.

Integrating Equation 18.49 gives the following for a component of a mixture of real gases

$$RT \ln \frac{\bar{f}_i}{f^\circ} = \int_{P_o}^{P} \bar{V} dP \quad (18.50)$$

Equation 18.50 is analogous to Equation 18.43 for a pure component. Both give the activity, i.e. ratio of fugacities. Fugacities are not as convenient for vapor-liquid equilibria work as fugacity coefficients and the activity coefficients, however.

Fugacity and Activity Coefficients. These coefficients were defined under Equation 18.6 as:

$$\frac{\bar{f}_i}{Py_i} = \phi_i = \text{fugacity coefficient}$$

$$\text{and } \frac{\bar{f}_i}{f_i x_i} = \gamma_i = \text{activity coefficient.}$$

Activity and activity coefficient are related as follows:

$$\bar{a}_i = x_i \gamma_i = \frac{\bar{f}_i}{f_i} = \text{activity}$$

Activity does not vary with concentration as much as does the activity coefficient. This is due to the mole fraction term in the coefficient and not in the activity. This would be an advantage for the activity except for the fact that mole fraction is required in the formulation of an equilibrium vapor-liquid distribution ratio.

The fugacity coefficient is used more frequently for the vapor phase, hence the symbol y_i is used for the mole fraction. The activity coefficient is used more frequently for the liquid phase, hence the symbol x_i is used for the mole fraction. There is no theoretical reason why each could not be applied to both phases.

The fugacity coefficient is the ratio of the fugacity of the component in the vapor mixture to its partial pressure. The activity coefficient is the ratio of the fugacity of the component in the liquid mixture to the product of a pure component reference state fugacity and the mole fraction.

This activity coefficient reference state may be at any convenient pressure but must be at the system temperature. There are three logical possibilities; i.e. (1) system pressure, (2) vapor pressure, and (3) atmospheric pressure.

Expressions for computing the fugacity and activity coefficients from P-V-T-C data are obtained by starting with the equations relating free energy, fugacity with volume and pressure and integrating to pure real gas datum points, thus introducing mole fraction and pressure or pure component fugacity.

The free energy of ideal gas mixtures is required in this development. It has been shown that the entropy for ideal gaseous mixtures is

$$S^\circ = \Sigma N_i S_i^\circ - R\Sigma N_i \ln \frac{N_i}{\Sigma N_i} \quad (18.51)$$

Combining with $F^\circ = H^\circ - TS^\circ$ gives the free energy for an ideal gas mixture

$$F^\circ = \Sigma N_i H_i^\circ - T\Sigma N_i S_i^\circ + RT\Sigma N_i \ln \frac{N_i}{\Sigma N_i} \quad (18.52)$$

The first two terms on the right hand side are equal to $\Sigma N_i F_i^\circ$, which gives

$$F^\circ = \Sigma N_i F_i^\circ + RT\Sigma N_i \ln \frac{N_i}{\Sigma N_i} \quad (18.53)$$

Combining Equation 18.53 with 18.33, Calling $F_2 = F$ and $F_1 = F^\circ$, gives

$$F = \int_{P_o}^{P} V dP + \Sigma N_i F_i^\circ + RT\Sigma N_i \ln \frac{N_i}{\Sigma N_i} \quad (18.54)$$

Differentiating Equation 18.54 with respect to N_i is the next step. This involves the following intermediate partial differentiations

$$\frac{\partial(\Sigma N_i F_i^\circ)}{\partial N_i} = F_i^\circ \quad (18.55)$$

$$\frac{\partial\left(\Sigma N_i \ln \frac{N_i}{\Sigma N_i}\right)}{\partial N_i} = \ln x_i \quad (18.56)$$

where: $x_i = N_i / \Sigma N_i$

These are straightforward and will not be developed in detail.

Combining Equations 18.54, 18.55, and 18.56 gives the following important relationship:

$$\mu_i = \frac{\partial F}{\partial N_i} = \int_{P_o}^{P} \left(\frac{\partial V}{\partial N_i}\right) dP + RT \ln x_i + F_i^\circ \quad (18.57)$$

Equation 18.57 leads to an expression for the fugacity coefficient of mixture components. This is done by

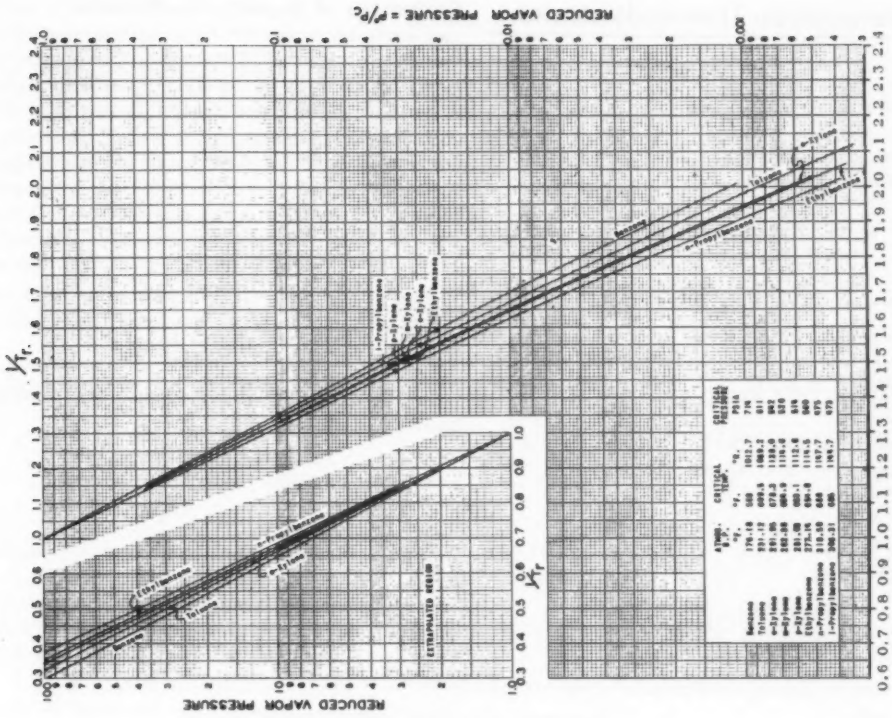


FIGURE 18.6—Reduced vapor pressures of aromatics.

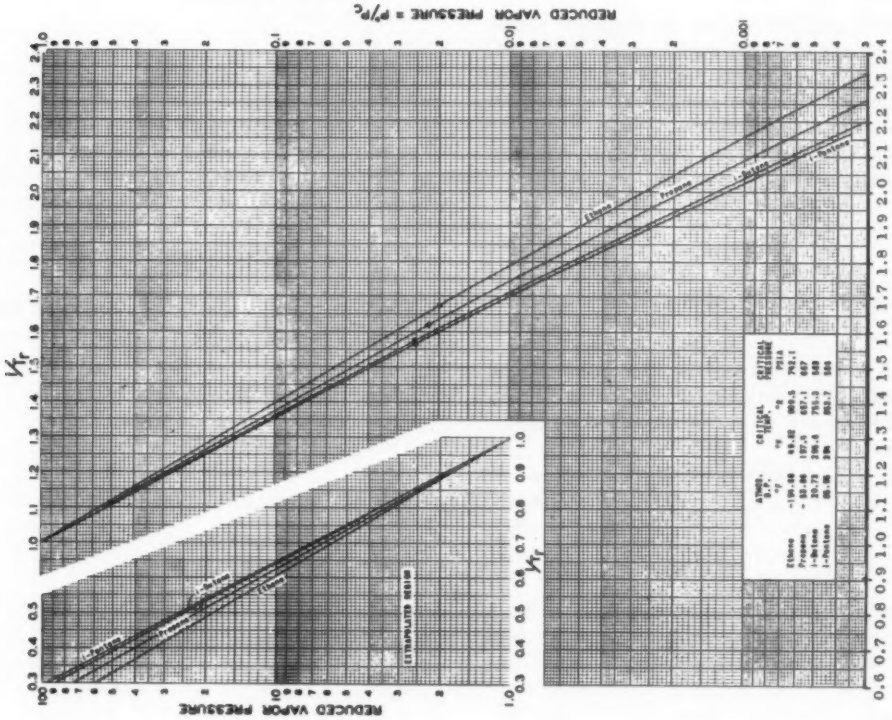


FIGURE 18.5—Reduced vapor pressures of olefins.

applying Equation 18.57 to a mixture of real gases, for which, by definition

$$\int_{P_o}^{P} \left(\frac{\partial V}{\partial N_i}\right) dP = \int_{P_o}^{P} \overline{V} dP = RT \ln \frac{\overline{f}_i}{f_i^o} \qquad (18.58)$$

Combining Equations 18.57 and 18.58 and changing x_i to y_i gives the following for a mixture of real gases

$$\mu_i = RT \ln \frac{\overline{f}_i y_i}{f_i^o} + F^o \qquad (18.59)$$

By choosing an ideal gas reference state, where $\overline{f}_i^o = y_i P_o$, Equation 18.59 becomes

$$\mu_i = RT \ln \frac{\overline{f}_i}{P_o} + F_i^o \qquad (18.60)$$

An expression for $\ln \frac{\bar{f}_i}{Py_i}$ can now be derived. Combining Equations 18.57 and 18.60 with $\bar{V}_i = (\partial V/\partial N_i)$, eliminating μ_i and F_i° gives

$$RT \ln \frac{\bar{f}_i}{y_i P_o} = \int_{P_o}^{P} \bar{V}_i dP \qquad (18.61)$$

Replacing $\bar{V}_i$ by its equivalent $RT/P - \bar{\alpha}_i$ and integrating gives

$$RT \ln \frac{\bar{f}_i}{y_i P_o} = RT \ln \frac{P}{P_o} - \int_{P_o}^{P} \bar{\alpha}_i dP \qquad (18.62)$$

The similarity of Equations 18.45 and 18.62 should be noted. Collecting terms and letting P_o the lower integration limit be equal to zero gives

$$\ln \frac{\bar{f}_i}{y_i P} = -\frac{1}{RT} \int_0^P \bar{\alpha}_i dP \qquad (18.63)$$

$$\ln \frac{\bar{f}_i}{y_i P} = -\frac{1}{RT} \int_0^P \left(\frac{RT}{P} - \bar{V}_i \right) dP \qquad (18.64)$$

where: $\bar{f}_i/y_i P = \phi_i$ = fugacity coefficient of "i" in mixture of real gases.

Equations 18.63 and 18.64 give the fugacity coefficient for a component of either vapor or liquid phases. It is more frequently used in this form for vapor phase components. Equation 18.64 is used in developing an expression for the activity coefficient.

Subtracting Equation 18.46 from 18.64 and replacing α by $(RT/P - V)$ and changing y_i to x_i gives

$$\ln \frac{\bar{f}_i}{x_i f_i} = -\frac{1}{RT} \int_0^P (V_i - \bar{V}_i) dP \qquad (18.65)$$

where: $\bar{f}_i/x_i f_i = \gamma_i$ = activity coefficient of "i" in liquid mixture.

Equation 18.65 may also be applied to either vapor or liquid phases. Mole fraction is indicated by x_i because activity coefficient is usually evaluated for liquid phase components.

Equations 18.64 and 18.65 are rigorous expressions relating ϕ_i and γ_i to the PVT data for gas and liquid mixtures. With sufficiently complete and accurate PVT data the fugacity and activity coefficient can be computed by these equations.

Equation 18.65 cannot be used to calculate γ_i for a component in a liquid mixture at a temperature and pressure where the component in question could not exist as a pure liquid. This would be true for gases in solution. For such a situation $\bar{V}_i$ could be evaluated but V_i could not be obtained.

In like manner γ_i could not be found by Equation 18.65 for a component of a vapor mixture at a temperature and pressure where the component in question could not exist as a pure vapor. Examples are the volatilized heavy components of equilibrium vapor over a mixture containing high boilers. In such a situation $\bar{V}_i$ could be evaluated but V_i could not be obtained.

Evaluation of Fugacity Coefficients. Fugacity coefficients can be evaluated from an equation of state that has been fitted to PVT data. For this purpose the equation of state must fit the PVT data of the pure components and the mixture as well. These data fits are accomplished by developing a set of constants for each component and then combining these constants to get constants for any mixture of the components. This method can be applied to multicomponent mixtures as well as binary systems, but the latter are much simpler and for this reason have been investigated more.

Two other methods for evaluating fugacity coefficients will be discussed first before going further into equation of state fugacity calculations.

Ideal Mixtures. When Amagat's law of additive volumes holds and

$$\bar{V}_i = V_i$$

and Equation 18.65 reduces to

$$\bar{f}_i = x_i f_i \qquad (18.66)$$

Equation 18.66 gives the fugacity of a component in a mixture from the pure component fugacity at the same temperature and pressure. This is an *ideal mixture*. Equation 18.66 is known as the "Lewis and Randall Fugacity Rule" and has been applied to both liquid and vapor phases in obtaining Equation 18.7

Dividing both sides of Equation 18.66 by pressure and rearranging gives

$$\phi_i = \frac{\bar{f}_i}{x_i P_i} = \frac{f_i}{P} = \nu_i \qquad (18.67)$$

Thus for a component of an ideal mixture, $\phi_i = \nu_i$.

The pure state fugacity-pressure ratio may be found from PVT data by Equation 18.46 at conditions where the values of α are known from zero pressure to the system pressure. Generalized f/P correlations have been developed from correlations of α and Z $(= PV/RT)$.

Generalized Fugacities Coefficients for Pure Components. The f/P values for pure components have been found from generalized correlations of PVT data using Equation 18.46 or its equivalents

$$\ln \frac{f}{P} = \frac{1}{RT} \int_0^P \left(V - \frac{RT}{P} \right) dP \qquad (18.68)$$

In terms of the reduced volume residual

$$\alpha_r = \frac{\alpha}{\alpha_C} = \frac{RT/P - V}{RT_C P_C - V_C},$$

where: α_r is a generalized function of T_r and P_r, ln f/P becomes

$$\ln \frac{f}{P} = -\frac{P_C \alpha_C}{RT_C} \frac{1}{T_r} \int_0^{P_r} \alpha_r dP_r \qquad (18.69)$$

An average value of the group of constants $P_C \alpha_C / RT_C = 0.724$ with very little variation for all light hydrocarbons. This permits preparing a generalized chart for f/P as a function of T_r and P_r. Values of f/P were found from Equation 18.69 by graphical integration of a plot of α_r vs. P_r for lines of constant T_r. In terms of the compressibility factor $Z = PV/RT$, where Z is a function of T_r and P_r, ln f/P becomes

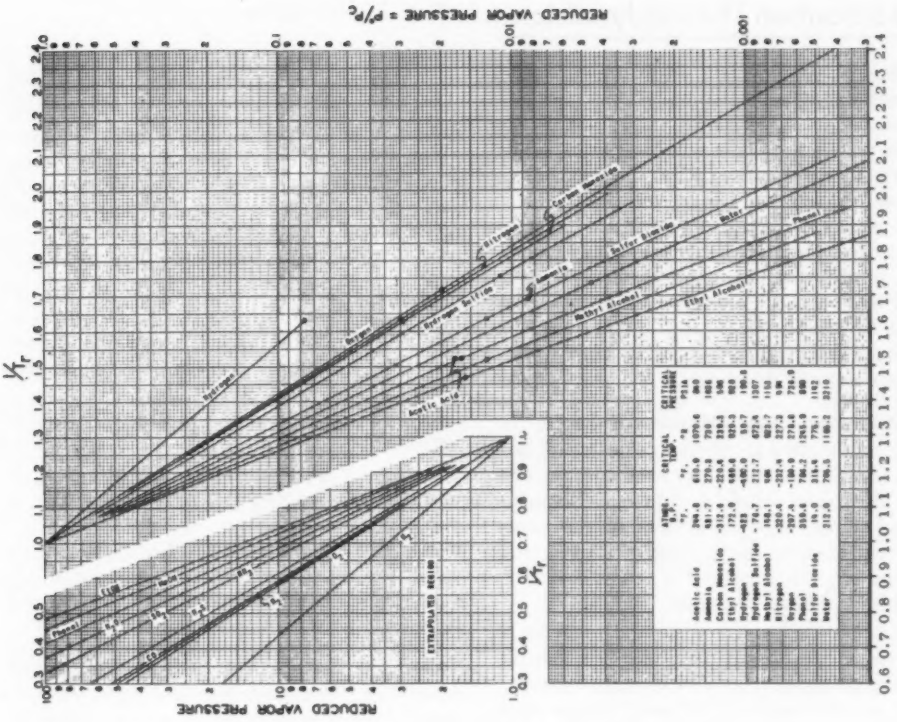


FIGURE 18.8—Reduced vapor pressures of miscellaneous compounds.

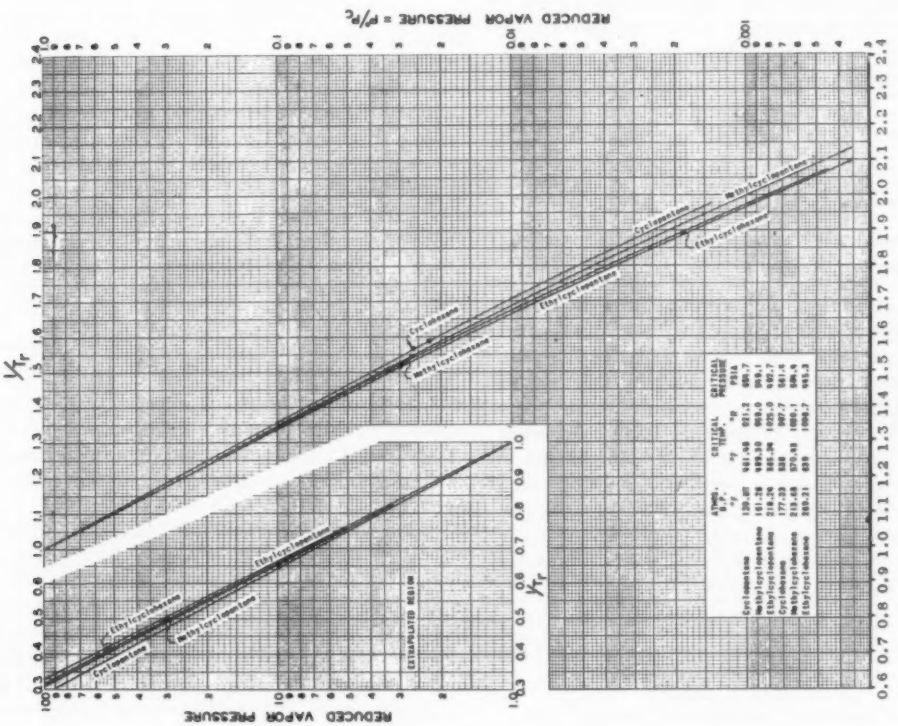


FIGURE 18.7—Reduced vapor pressures of naphthenes.

$$\ln \frac{f}{P} = \int_{O}^{P_r} (Z-1)\, d \ln P_r \qquad (18.70)$$

When applied carefully to the same data, Equations 18.69 and 18.70 give the same values of f/P. The integrations are performed at constant temperature from zero pressure to the pressure of interest.

At T_r values of 1.0 and greater, which isotherms are continuous from zero to higher than unity reduced pressures, the f/P values can be evaluated by this integration for all pressure of interest. At lower than unity T_r values, however, this integration is only possible up to the vapor pressure with the ordinary compressibility factor correlations. Other methods must be used for

finding f/P values at higher than saturation pressures for these temperatures.

Figure 18.1 is a plot of f/P ratios vs. T_r and P_r for pure gases. This plot is a composite of the work of W. K. Lewis and W. C. Kay[4] and of R. H. Newton.[5] This type of generalized correlation was the basis for the well known MIT K charts. The values of f/P for the less-than-unity reduced isotherms were extended to higher-than-saturation pressure by the use of some experimental vapor-liquid equilibrium data. In estimating vapor-liquid equilibria K values this chart is applied to both phases in the manner illustrated in an example after further chart development discussion.

Fugacity K Values for Ideal Mixtures. The f/P vs. P_r and T_r chart can be used to get the values of f_i^L and f_i^V in Equation 18.7. The use of this chart in the evaluations of vapor fugacities should be obvious. Knowing the pressure and temperature conditions of the vapor and its critical temperature and pressure, reduced conditions are computed; values of f/P is found and f^V is found by multiplying by the pressure.

This chart may be used to calculate the fugacity of liquids at their vapor pressure by using the fact that the fugacity of a pure component as a saturated vapor and saturated liquid are the same at the same temperature and pressure. This follows from the fact that the saturated vapor and liquid phases of a pure component are in equilibrium plus the limitation to ideal mixtures. Expressed mathematically,

$$f^{L}_{P_i^\circ} = f^{V}_{P_i^\circ} \qquad (18.71)$$

where: $f^{L}_{P_i^\circ}$ = the fugacity of component as a liquid at the vapor pressure.

$f^{V}_{P_i^\circ}$ = the fugacity of component as a vapor at the vapor pressure.

From Equation 18.71, it can be seen that the fugacity of a saturated liquid can be estimated from the f/P chart by finding the corresponding vapor fugacity. Liquid fugacities obtained from the f/P chart by the method described above are at the vapor pressure at the given temperature. The system pressure is higher or lower than the vapor pressures of most of the components in the mixture. This difference in pressure should be taken into consideration in computing the liquid fugacities of these components. This is done by applying the basic equation for the fugacities between the vapor pressure and the system pressure, as follows:

$$RT \ln \frac{f^{L}_{P}}{f^{L}_{P_i^\circ}} = \int_{P_i^\circ}^{P} V \, dp \qquad (18.72)$$

where: f^{L}_{P} = liquid fugacity of component at system pressure

$f^{L}_{P_i^\circ}$ = liquid fugacity of component at vapor pressure.

Replacing V by ZRT/P and integrating with an average compressibility factor gives

$$\ln \frac{f^{L}_{P}}{f^{L}_{P_i^\circ}} = Z_{av} \ln \frac{P}{P_i^\circ} \qquad (18.73)$$

which may be written

$$\frac{f^{L}_{P}}{f^{L}_{P_i^\circ}} = \left(\frac{P}{P_i^\circ}\right)^{Z_{av}} \qquad (18.73)$$

Equation 18.73 is a means of correcting the liquid fugacity from the vapor pressure to the system pressure. The exponent, Z_{av}, may be found from Figure 18.2 where it is given as a function of reduced temperature and log mean average reduced pressure (i.e., log mean average of reduced vapor and system pressure). The dash line example shows how this chart is read.

The Z_{av} Chart in Figure 18.2 was prepared by combining the liquid phase compressibility factors with the graph for evaluating the log mean average, these two being the lower and upper parts.

Combining Equations 18.7 and 18.8 gives the following expression for the Lewis and Randall K values:

$$K_{Ideal} = \frac{P_i^\circ}{P}\left(\frac{f P_i^\circ / P_i^\circ}{f_P/P}\right)\left(\frac{P}{P_i^\circ}\right)^{Z_{av}} \qquad (18.74)$$

Values of $f_{P_i^\circ}$ and f_P/P are found from the f/P Chart for each component, using reduced vapor pressure and reduced pressure, respectively, at the same reduced temperature for each component.

Vapor Pressures. Vapor pressures are also required in applying these correlations. Vapor pressures were required over a wide range of temperatures for converting the pure fugacity coefficients (f/x) to mixture fugacity coefficients ($f/P_i^\circ x$) in developing the generalized correlation described next. Values were obtained as follows:

(a) API Research Project 44 and (b) a straight line on log P versus 1/T scales was used from the atmospheric boiling point through the critical point. A straight line on log P versus 1/T scales gives a logical and reproducible method of extrapolation to temperatures above the critical. It is not possible to generalize vapor pressures completely. However, the use of reduced scales does consolidate the vapor pressure plots. The reduced vapor pressure charts are given as Figures 18.3, 18.4, 18.5, 18.6, 18.7, and 18.8 and recommended for use with the generalized fugacity coefficient correlation.

MIT K Charts. Charts of vapor-liquid equilibrium K values for hydrocarbons were prepared from the f/P vs. P_r and T_r correlation and some experimental data on the solubility of light gases in the early 1930s at MIT.

There are two significant features of this development: (1) the f/P vs. P_r curves at $T_r < 1.0$ were drawn in by the use of experimental data. The f/P chart of Kay & Newton is therefore partly empirical. It is not entirely derived from theoretical calculations based on a generalized correlation of pure component PVT data; and (2) liquid fugacities were extrapolated above the critical point to get the values for lighter components in solution.

Using experimental K values, as mentioned above, in the construction of the basic f/P correlation gives K charts that contain some corrections for deviations from ideal solutions. Thus the MIT charts do not give completely ideal K values, even though temperature and pressure are the only variables.

Thus, the f/P chart was prepared by extrapolation

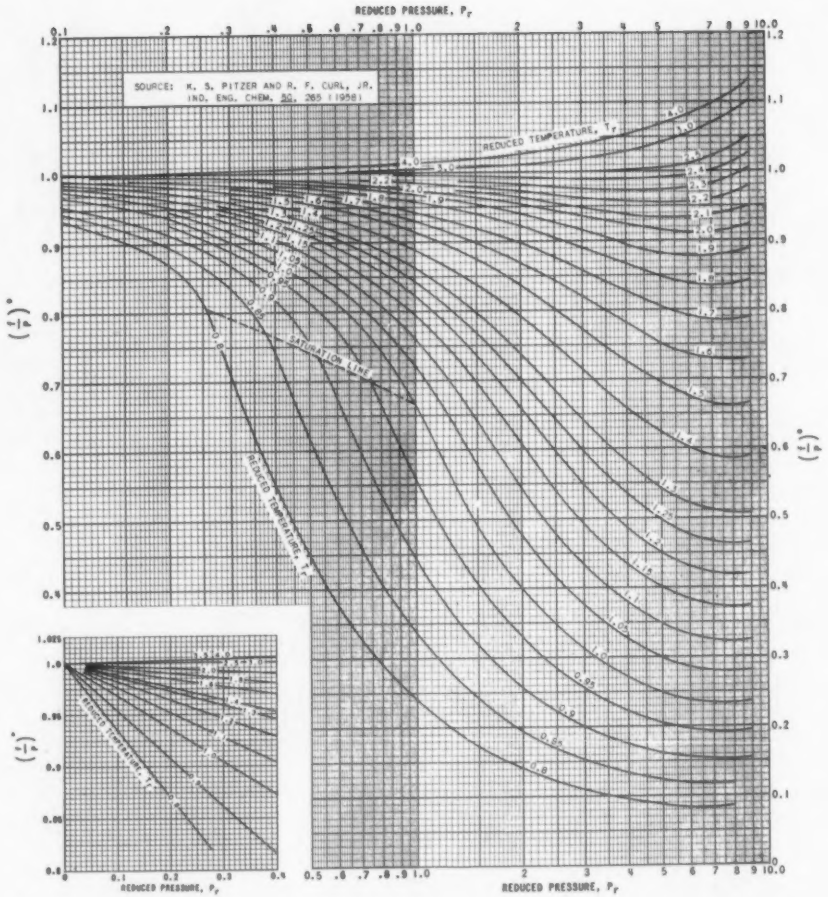
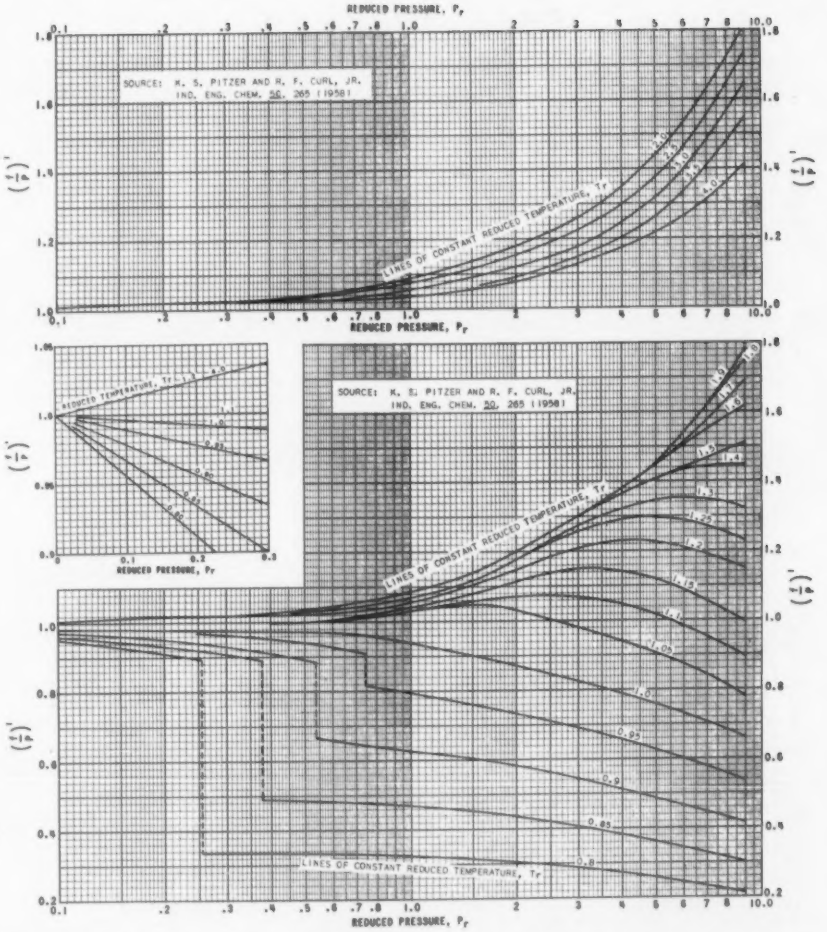

REDUCED PRESSURE, P_r
SOURCE: K. S. PITZER AND R. F. CURL, JR. IND. ENG. CHEM. 50, 265 (1958)
REDUCED TEMPERATURE, T_r
SATURATION LINE
REDUCED TEMPERATURE, T_r
$(\frac{f}{P})$
$(\frac{f}{P})'$

FIGURE 18.9—Generalized activity coefficients for simple fluids.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SOURCE: K. S. PITZER AND R. F. CURL, JR. IND. ENG. CHEM. 50, 265 (1958)
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$(\frac{f}{P})'$
$(\frac{f}{P})$

FIGURE 18.10—Generalized activity coefficients for correction factors for deviation from simple fluid.

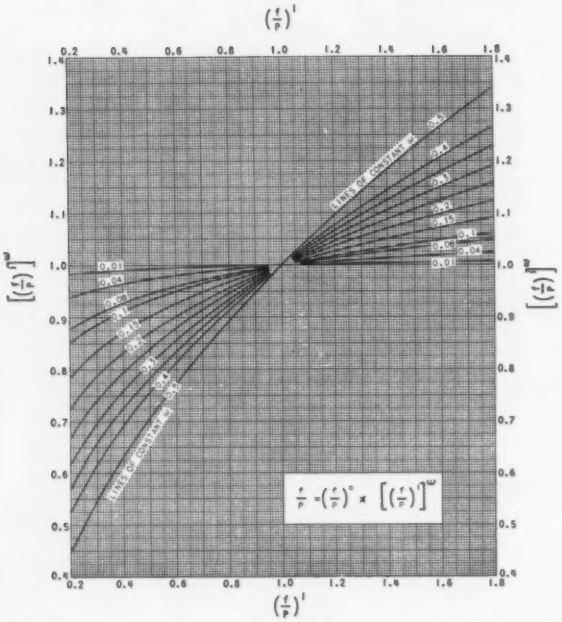

FIGURE 18.11—Generalized activity coefficients conversion chart.

in the lower reduced temperature range. Its application in the higher reduced temperature range requires extrapolation also, i.e. either vapor pressures or fugacities or both. Accordingly, charts based on this correlation are partly empirical.

The f/P vs. P_r and T_r chart, derived from vapor PVT data and some K data, as described above, is applied to both liquid and vapor phases as will be illustrated in examples given later. Liquid phase fugacities are found by computing the f/P ratio at the system temperature and vapor pressure and then correcting the fugacity to the system pressure by Equation 18.73, as illustrated by the following example.

Example 1. Find the ideal K value of propane at 100° F. and 300 psia. This example illustrates the method used in preparting "MIT Type" K charts.

Solution. The equation for this type of K value is as follows:

$$K_i = \frac{y_i}{x_i} = \left(\frac{f_{P_i^\circ}/P_i^\circ}{f_P/P}\right)\left(\frac{P}{P_i^\circ}\right)^{Z_{av}}$$

P_i°, vapor pressure, is found from the reduced vapor pressure chart, Figure 18.3, $1/T_r = 66/(100 + 460) = 1.19$ and the value of $P_i^\circ/P_c = 0.305$. $P_i^\circ = (0.305)(617.4) = 188.5$ psia.

fP_i°/P_i°, the liquid activity coefficient, is found from the f/P Chart, Figure 18.1, at $T_r = (100 + 460)/666 = 0.84$ and $P_r = P^\circ/P_c = 188.5/617.4 = 0.305$ as 0.796.

f_P/P, the vapor activity coefficient, is also found from Figure 18.1 at $T_r = 0.84$ and $P_r = P/P_c = 300/617.4 = 0.485$ as 0.695.

The exponent Z_{av} is evaluated from the Z_{av} Chart, Figure 18.2. Enter at 0.485 travel horizontally to 0.305, travel vertically to 0.84, and read Z_{av}, compressibility factor of the liquid at the log mean average of P° and P, as 0.073.

$$\text{Then } K = \left(\frac{188.5}{300}\right)\left(\frac{0.796}{0.695}\right)\left(\frac{300}{188.5}\right)^{0.073} = 0.74$$

Improved Pure Component f/P Correlation. Figures 18.9, 18.10, and 18.11 give an improved generalized f/P correlation for pure substances. These charts were prepared from tabulations of $[\log (f/P)]^\circ$ and $[\log(f/P)]'$ values prepared recently by Pitzer et al[6] from their improved generalized compressibility factor correlation. (See Part 4 of this series in the April 1958 Refiner.)

In this work the quantities $[\log(f/P)]^\circ$ and $[\log (f/P)]'$ are each given as functions of T_r and P_r. The fugacity/pressure ratio $(f/P)^\circ$ is the value of (f/P) for the simple fluid while the $(f/P)'$ ratio is the correction for deviation from the simple fluid. These ratios are related as follows:

$$\log \frac{f}{P} = [\log (f/P)]^\circ + \omega[\log(f/P)]' \qquad (18.75)$$

$$\frac{f}{P} = \left(\frac{f}{P}\right)^\circ\left[\left(\frac{f}{P}\right)'\right]^\omega \qquad (18.76)$$

where: ω = acentric factor

Figures 18.9 and 18.10 are plots of $(f/P)^\circ$ and $(f/P)'$ vs. T_r and P_r while Figure 18.11 is a graphical evaluation of the fractional powers of $(f/P)'$.

These charts are for pure components only. They are applicable to both liquid and vapor phases. At less-than-unity reduced temperatures, the breaks between gas and liquid are indicated. It is of interest to note that the reduced isotherms are continuous and without sharp breaks on the $(f/P)^\circ$ plot, as can be seen on Figure 18.9. On the $(f/P)'$ plot these less-than-unity reduced isotherms shift to lower $(f/P)'$ values at the saturation pressure, as can be seen on Figure 18.10.

These two graphical representations of the phase transitions indicate that the liquid and vapor f/P values for a simple fluid are the same. It might be possible to apply Figure 18.9 to the computation of ideal K values via the Lewis and Randall rule. More will be presented on this matter.

Prausnitz[7] has recently developed a generalized f/P correlation for the hypothetical vapor state. In this correlation f/P is given as function of P_r, T_r, and ω. This work will be covered in a later installment.

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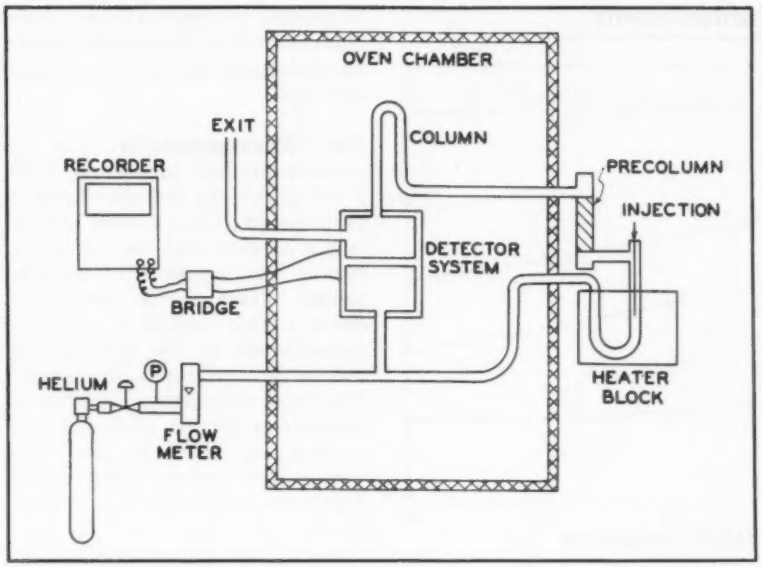

FIGURE 1—The secret to this chromatographic technique is the heater block, precolumn and oven chamber as shown above.

Here's Better Test for Flash Point Contaminants

Specialized gas chromatography finds what and how much contaminant is responsible for flash point change

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California Research Corp., Richmond, Calif.

FLASH POINT, designed primarily to determine explosion and fire hazard, has also been widely used to measure contamination due to volatile components in relatively nonvolatile mixtures.[1] Such measurements are required in a variety of situations such as the detection of monomers and degradation products in polymer systems, the determination of residual solvent in treated products, and the measurement of fuel dilution in lubricating oils.

Flash point is useful but not entirely satisfactory for such analyses. It gives no information as to the identity of the volatile components. Concentrations cannot be measured directly unless the volatile components are of known and unchanging composition, and the test fails if volatile components, or diluents, are noncombustible.

These limitations indicate the need for a universal analysis for volatile components. This is possible by a technique recently described.[6] A schematic diagram of the apparatus is shown as Figure 1. The method uses a heater block to vaporize volatile components into a stream of helium. The gas stream passes through a short precolumn and then to a conventional gas chromatography. The heavy or nonvolatile fractions from the sample are trapped in the precolumn. The volatile components are resolved and analyzed as in conventional gas chromatography.

In developing a contamination analysis, tests have been made by flash point and by gas chromatography on over 25 synthetic blends. The systems tested are shown in Table 1. Tests were made at a minimum of three concentrations in the range of 0.1-10.0% of volatile components. Micro open cup and Pensky-Martens closed cup flash point tests were used.[2,3]

TABLE 1—Test Systems

	Contaminant	Carrier
1.....	Methyl ethyl ketone	150 Neutral Oil
2.....	Chloroform	150 Neutral Oil
3.....	Ethylene chloride	150 Neutral Oil
4.....	Benzene	480 Neutral Oil
5.....	n-Decane	480 Neutral Oil
6.....	2-Ethyl-1-butanol	Polysiloxanes
7.....	2-Ethyl-1-hexanol ..	Polysiloxanes

The solvents used are defined in Table 2.

TABLE 2—Solvent Description

Solvent	Identification
150 Neutral Oil	API Gravity, 30.1; Viscosity, 100° F, 145 SSU†
480 Neutral Oil	API Gravity, 28.5; Viscosity, 100° F, 528 SSU†
Polysiloxanes	Mainly di- and trisiloxanes with 15% di-2-ethylhexy sebacate*

† Asphalt extracted petroleum base stocks.
* Composition of MIL-H-8446B and high temperature hydraulic fluid[4].

Systems 1, 2, and 3 in Table 1 are closely akin to those encountered in solvent treating of petroleum fractions. Methyl ethyl ketone, for example, is used to extract oils from wax. Systems 4 and 5 simulate typical contamination problems. Systems 6 and 7 are analyzed daily in the manufacture of aviation hydraulic fluids. Alcohols also appear as contaminants in asphalt and wax removal processes.[5]

Typical flash point and gas chromatographic analyses are shown in Table 3 for Systems 4, 6, and 7.

Flash Point. Table 3 indicates changes in flash point with diluent concentration. It may be seen that the Pensky-Martens closed cup tests

Better Test for Flash Point Contaminants . . .

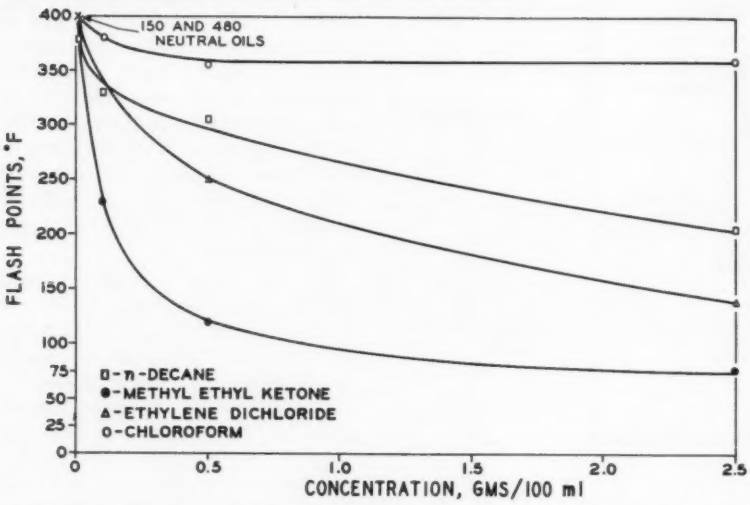

FIGURE 2—Correlates flash point data for several other systems listed in Table 1 showing the Pensky-Martens flash tests of oils containing these individual compounds.

are far more consistent and sensitive to diluents than open cup flashes. Figure 2 correlates flash point data for several other systems listed in Table 1. The sensitivity of flash point tests is found to decrease markedly with increasing concentration of each diluent.

Incremental changes in flash point also vary widely with diluent type. Figure 2 indicates that an increase in methyl ethyl ketone concentration to 2.5 percent gives about a tenfold greater decrease in flash than the same increase in concentration of chloroform. Table 3 and Figure 2 also indicate the vast difference in response to flash tests of methyl ethyl ketone, benzene, and chloroform; yet, their boiling points differ by less than 10° F.

Mixed solvents are frequently used in refining processes. For such cases flash point is an inadequate method for evaluating diluent concentration and type.[5]

TABLE 3—Analysis for Volatile Diluent

Diluent System Studied	Made Up Percent g/100 ml	Gas Chromatographic Analysis	Flash Points, °F	
			Pensky-Martens	Micro Open Cup
Benzene in 480 Neutral Oil	0	0	405	485
	0.2	0.2	216	505
	0.5	0.5	156	495
	1.0	1.0	114	520
	5.0	4.6	80	290
2-Ethyl-1-butanol in Polysiloxanes	0	0	315	415
	1.0	0.9	202	430
	5.0	4.9	170	425
	10.0	10.3	152	165
2-Ethyl-1-hexanol in Polysiloxanes	0	0	315	415
	1.0	0.9	235	410
	5.0	4.6	206	410
	10.0	10.3	190	250

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Gas Chromatography. The gas chromatographic analyses in Table 3 are largely the average of two or more results. The precision and accuracy of these tests are ± 10 percent of the amount of contaminant present. There are no consistent errors in this method as has been demonstrated in 100 previous determinations with this instrument.[6] The blank or zero concentration determination on the carrier showed no peaks on the carrier alone. The carriers used were all highly treated fluids; the polysiloxane was nitrogen blown.

Typical chromatographic determinations for volatile contaminants are shown in Figure 3. The amounts of contaminants are proportional to peak areas. From retention times, the diluent may be identified by comparison with known substances. The diluent concentration is obtained directly in percent from the chromatographic chart by dividing the peak area for the diluent by the peak area for an internal standard. The standard is volumetrically added to the original sample in 1 percent concentration before analysis.

The chromatographic apparatus and operational details are presented in Reference 6.

For normal chromatographic detector response, the peak areas on the recorder chart are proportional to weight percent. The standard is a substance which has a thermal conductivity similar to that of the diluent and one which gives a different retention time. Standards used on the systems shown in Table 2 include normal alkanes with from 6-12 carbon atoms. If desired, calibration corrections may be made for differences in detector response. The standard can be chosen to emerge before or after the diluent fractions. Actually, the analysis can be performed without a standard. However, this requires uniform and precise sample injection and constant column conditions. The use of a standard compensates for many experimental variables.

Discussion. Results confirm common knowledge that flash point tests

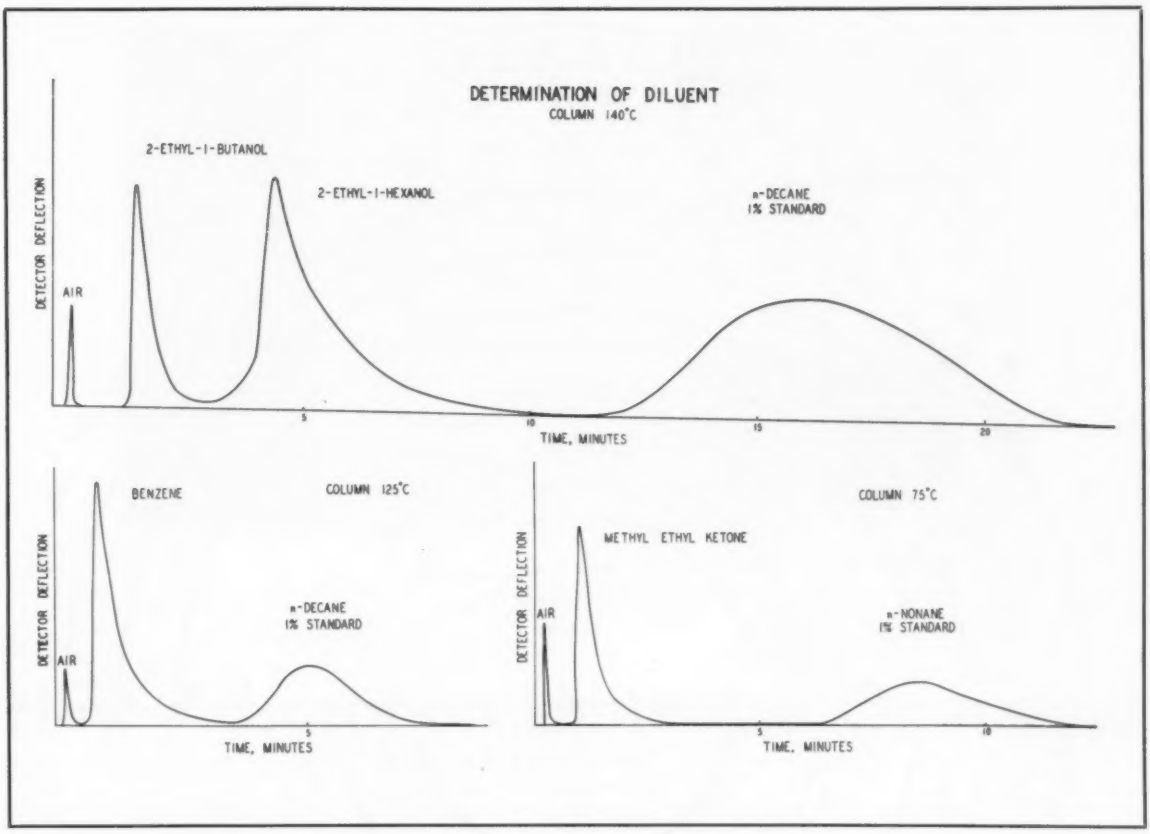

FIGURE 3—Shows typical chromatographics for volatile contaminants. The amounts of contaminants are proportional to peak areas. By using the known standard shown on each chart the diluent concentration is obtained directly in percent by dividing the peak area for the diluent by the peak area for the internal standard.

offer a useful analysis in many cases. Gas chromatographic tests, however, give more informative results in every case. Flash point tests cannot provide diluent identification and, at best, measure diluent concentrations with a precision and sensitivity comparable to gas chromatography. The chromatographic analysis may be applied universally to contaminants boiling between 75° and 425° F, irrespective of diluent complexity and molecular type. Flash tests over this temperature range require the use of two or more flash point methods.[7] Flash point instrumentation is not completely standardized, so that different methods will give uncertain agreement.

Both flash point and chromatographic tests are most satisfactory when diluent boiling points are much lower than that for the carrier. Each test, however, may be applied to systems with a continuous range of volatilities. For this case, heater block temperatures on the chromatograph are adjusted to give the desired cutoff. In this way the chromatographic test may be correlated with initial boiling point temperatures in ASTM or Engler-type distillations.[8]

In a number of important systems, such as those involving noncombustibles, the chromatographic method is the most convenient method of analysis. For example, water is a common contaminant of refinery streams,[5] yet the presence of water leads to unreliable flash point data.[5,7] The chromatographic method also handles unambiguously a diluent composed of two or more components in variable ratios.[6] This feature is very important, as frequently a blend of volatile liquids gives the desired balance of physical properties in treating processes.

The sensitivity range of the chromatographic method is large, greater than 0.05-10 percent. The method is also independent of atmospheric pressure and apparatus variables, in contrast to the flash test. The chromatographic test takes about five minutes of operator time and 30 minutes of machine time. The sample size required for gas chromatography is less than 1 cc or about 1/50 of that required in common flash point tests.

In general, gas chromatography appears to give more versatile and definitive analyses than flash point tests. It also has advantages over chemical analyses, vapor pressure measurements, and analytical distillations in determining volatile constituents. The cost of a gas chromatograph is comparable to that of an automatic flash point tester.

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Find Physical Properties of Methanol

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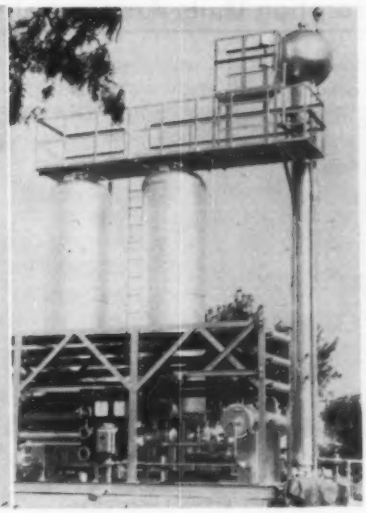
Geleen, Netherlands

THE ACCOMPANYING nomograph has been constructed from literature values. The upper part gives the physical properties of methanol liquid, the lower part those of the vapor. The nomograph is read as follows: Any line passing through the center intersects the scales in corresponding points. The temperature scale holds for both the liquid and the vapor. # #

11 Points to Consider

Application
Selection and bids
Control systems
Heaters
Dessicant
Mechanical
Accessibility
Pressure protection
Cycle time
Performance guarantees
Operating records



Texaco's adsorption unit at Hidalgo, Texas

How Adsorption Units Are Operating

Texaco has found the operation of its gas processing units to be routine after initial bugs were worked out

Howard Halff, Texaco Inc., Houston

TEXACO'S SHORT-CYCLE adsorption units for gas processing are now operating in a routine manner. But behind this development have been numerous problems which had to be worked out. Here are 11 points to consider in the light of Texaco's experience.

Application

Texaco's application's of short cycle adsorption units have been confined to field installed and operated units extracting up to 150 barrels per day of approximately 12# vapor pressure gasoline from lean gas streams. In actual cases, the content of the processed gas is less than 0.4 gpm of isopentane and heavier components. There is no reason to assume that this gpm constitutes a maximum content limit for economical processing by field adsorption, but it does appear that somewhere between ¾ and 1 gpm there is a point at which other processing methods (either alone or in combination with adsorption) would be economically competitive or more attractive. All of our existing units are operated by field personnel, usually pumpers.

For the type of installations here under consideration, we have not found it economical to recover LPG as a separate product. The equipment and operating costs to adsorb, fractionate, store and market the propane or LPG produced will be at least equal to the cost of producing a stabilized gasoline, and could be substantially higher in some plants. Almost all field processed gases will yield less LPG than gasoline and, of course, the price received for the light ends is generally considerably less than the market value of the gasoline. Most plants producing LPG will require a full operating force, thus adding to the operating costs and eliminating one of the most desirable features of the packaged adsorption unit—its ability to be operated by existing field personnel.

An exception might be the production of a mixed high vapor pressure product if a market for this type of liquid is available. This can be accomplished in the plant designed primarily for gasoline production, as all adsorption units condense a product having a vapor pressure equal to the unit's operating pressure (usually 500# to 1,000#) and it is a simple matter to stabilize or flash this liquid to some final vapor pressure other than 12#.

Our use, then, of these units in the field is primarily to "skim off the cream" of the liquid products. And incidentally, there may not be nearly as much "cream" as would appear at first glance. A number of units have been suggested which proved to be economically questionable or, in some cases, impossible. Such costs as depreciation and amortization of the equipment; royalty or lease payments; production, ad valorem, and income taxes; maintenance; desiccant replacement; and normal operating expenses can severely restrict the earning potential of a small plant. As a rule of thumb, any proposed unit with a potential production of 35 bpd or

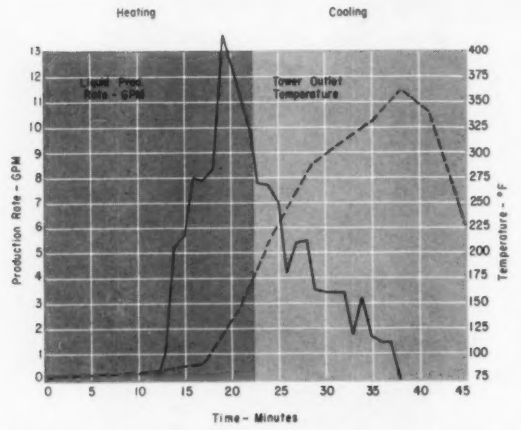

Heating
Cooling
Liquid Prod. Rate - GPM
Tower Outlet Temperature
Production Rate - GPM
Temperature - °F
Time - Minutes
0 5 10 15 20 25 30 35 40 45
0 1 2 3 4 5 6 7 8 9 10 11 12 13
75 100 125 150 175 200 225 250 275 300 325 350 375 400

FIGURE 1—Test run on a two tower closed cycle unit (at 45-minute switching intervals) shows that most liquid product is produced by end of heating cycle. Limiting temperature on residue gas prevents any further shortening of cooling period.

less should receive extremely careful consideration before its installation is approved. If a unit is considered on a pipe line, where direct compensation for fuel, shrinkage, and Btu reduction are required (rather than the usual field installation where these items are established at a nominal or deferred value) the economics are seriously affected. However, some such units, generally in the larger sizes, have been installed.

Selection and Bid Evaluation

Having decided to purchase a unit for a particular application, the normal procedure is to request bids from several manufacturers. And here begin the purchaser's problems. Manufacturer's staffs are overburdened preparing quotations, and many purchasers are dealing in an item with which they may be only vaguely familiar. These are both factors which promote discrepancies in the units offered.

While complete mechanical specifications may be unnecessary for a unit of this type, at least a summary mechanical detail, outlining required bypasses, block valves, safety devices, etc., should be furnished the suppliers so that equipment offered will satisfy the buyer's needs.

Adsorption has not yet developed to the extent of absorption, where there are some accepted bases for determining extraction. Each supplier apparently works from his own set of empirical data. Bid evaluation is thus complicated by the fact that claimed product recovery will probably vary substantially.

Open and closed cycle units will, each in turn, be praised and condemned; prices will vary over a considerable range depending on the type of unit presented and the auxiliary equipment included; heating and cooling equipment, fuel and utility requirements, desiccant capacity, cycle time, installation costs, safety devices, maintenance features, pressure drop, and many other factors must all be considered and evaluated.

From experience, features such as (1) the amount and type of foundations required, (2) how much insulation on heaters, stabilizers, lines, etc. is included and how much must be field applied, and (3) how much interconnecting piping is to be installed by the purchaser, will require extremely close examination of the quotations in order to arrive at a proper comparative evaluation. *We are, after all, dealing not with a standard item such as a tank or separator but, rather, with a processing plant; and it must properly be evaluated on this basis.*

There is no easy way to accomplish a correct bid comparison. Time, and most probably one or more sessions with each manufacturer's representative, are required. No purchaser who simply tabulates the claimed recovery and the quoted price of each unit can expect, with any assurance, to get the unit which will do the best job in his application, or to receive the highest return for each investment dollar.

Control Systems

The control systems for packaged units may be either pneumatic, electric or mechanical. For all types, because of the relatively large numbers of valves and sequence operations required, these systems are likely to be complicated to assemble, and it is recommended that a day or two be allowed prior to start-up of any unit to completely check out the controls and make any necessary corrections. Reliability is, of course, of primary importance. The general opinion among operators seems to be that existing control systems are satisfactory —none are yet perfect.

One of the operating items too frequently minimized in field units is the importance of control valves in securing maximum product recovery. All such valves should be checked regularly to insure that they seal tightly, operate freely, and respond instantly to the control signals. A switching valve which sticks in one position, fails to seal tightly, or is inoperative due to diaphragm failure, will quit effectively reduce plant production. Periodic inspections, plus a thorough check whenever production appears to be curtailed, will detect such failures and maintain maximum recovery.

Heaters

Heaters are a basic part of the process cycle and, because field plants are unattended most of the time, safety here should receive the most careful attention. In the event of tube failure, a large gas stream continues to be directed to the heater. A check valve on the heater outlet is standard equipment to prevent backflow of gas into the coils in the event of tube failure, but a more complicated device is required to sense and safely shut off flow from the unit into the heater. We have noted such safety devices that were overly sensitive, and shut off gas flow to the heater during normal operations, as well as devices not sufficiently sensitive to provide adequate protection.

Some units quoted have had the usual temperature controls and high temperature shutdowns on the heater, but have not had a safety device to shut off fuel in the event of pilot failure. Where there is even the remotest chance that hot metal, ceramics, another heater, or other installations nearby might ignite accumulated gas, a pilot safety device should be considered an absolute necessity.

On a number of installations, flash or stabilizer vapors

are used for fuel. If this is the case, extra care should be taken to prevent liquid from entering the heater fuel lines. An ineffective safety device here, coupled with a simple dump valve failure, practically insures destruction of the heater. Because the fuel supply regulator normally furnished on packaged units can cut out, releasing the full operating pressure of the unit into the fuel system, suitable relief devices should be installed and the valve should be checked periodically.

Assuming proper controls and application, both salt bath and direct fired heaters are, from our experience to date, satisfactory from an operating and a safety standpoint.

Desiccant

Perhaps the most unpredictable item in a dry bed unit is the desiccant. Regardless of the type of adsorbent utilized, performance can vary substantially from one plant to the next. Routine checks of recovery efficiency appear to be the best, if not the only, way to effectively evaluate performance in any particular unit.

Even more perplexing than performance can be the many locations around the unit where varying quantities of desiccant dust can mysteriously appear. In the earliest development stages of field units, a leaking support plate allowed us the privilege of delivering substantial quantities of desiccant for something less than 20¢ per thousand cubic feet. Considering the cost of desiccant, this was a real bargain, but for some strange reason the receiver failed to appreciate our philanthropy.

Since this initial incident no similar trouble has been encountered. However, accumulations of small particles of desiccant dust continue to appear in lines, accumulators, around dump valves, and on orifice plates. This situation quite naturally becomes more troublesome as the desiccant service time increases.

In one instance dust passed through an accumulator, a surge tank, and a stabilizer, and plated out in the stabilizer outlet lines. Apparently the flow rate and other conditions at these points were responsible. The deposition was concentrated in a 1-inch, 90-degree elbow, and on at least two occasions scaling was sufficient to cut off liquid flow completely. The scale formed was quite hard and had deposited in layers, as might be expected. Somewhat to our surprise, this scale was effectively removed by washing the lines with an ordinary water stream.

To protect the units and maintain maximum product recovery, sifting of desiccant at intervals of approximately six months, to remove fines and broken particles, has been instituted. These siftings are generally scheduled when the unit is down for other reasons, and the time intervals may be increased or decreased as operating conditions indicate. While it has not been considered necessary up to this time, installation of a filter to remove dust from any stream above the point where troublesome accumulations occur would be a relatively simple matter.

Mechanical

The use of closed cycle units, or of open cycle units with water or forced draft cooling, introduces additional pumps, blowers and/or motors into the adsorption process and, of course, adds to the operating and maintenance requirements.

The various gas pumps and blowers now in service for circulating regeneration gas, and as power for this purpose on gas drive units, have presented many problems to the designers and operators. All, apparently, are subject to accelerated wear caused by desiccant dust or any other foreign matter entering the pump chamber. Where tolerances are close, foreign particles can jam and stop a blower, and at times damage of this type is sufficient to require replacement. Filters or strainers now installed by manufacturers on the inlet to the pump chambers should serve at least to reduce trouble of this type.

Regular lubrication of gas pumps and blowers is of major importance. Where the pumps or blowers are enclosed, present designs provide for external lubrication while the unit is in operation, and a continuous automatic lubricator has been included on one manufacturer's unit.

For a small additional cost, any closed cycle unit may incorporate features which will enable it, either manually or automatically, to change to an open cycle flow pattern whenever the gas circulating equipment is inoperative. This provides gas dehydration and liquid recovery during any trouble period, and is recommended as an inexpensive means of insuring continuous operation.

Where electric motors are used as power for circulating regeneration gas or for fans or pumps, it should be kept in mind that unattended operation increases the possibility of completely burning out any motor when failure occurs. Careful selection of fuses, heaters and other electrical safety devices can greatly reduce the number of motor replacements which have been experienced by various operators of these units.

Accessibility

When units are fully fabricated at the factory, cost or space factors may dictate that certain portions of the unit be built with limited accessibility. Where it is probable that access to the internals of a vessel or exchanger will never be required, such cost savings can be worthwhile. However, a purchaser should insure himself that he has not, under the guise of economy, purchased a unit where inaccessibility will make maintenance inconvenient or even, in some cases, impossible.

Desiccant fill openings on the main tower should be large enough to permit rapid and convenient filling. Smaller openings for removal of the desiccant have proved to be very convenient, as the desiccant flows out freely and can be easily controlled from a 3″ or 4″ opening.

Any moving part, such as a motor, pumps or blowers, should be designed for convenient inspection and removal, and if individual units are too heavy to be handled by one man, suitable lifting aids should be considered.

Pressure Protection

Some units have been equipped with bursting plates as protection against excess pressure. While these are certainly positive relief devices, they have definite disadvantages on plants of this type. The sudden relief of

pressure at one point can scatter desiccant throughout all lines leading from the towers to the bursting plate, and there is some evidence that sudden release of pressure causes shattering of the desiccant. Excessive pressure drop across the valves can be harmful to seats, stems, or diaphragms. Large volumes of gas can be flared before the rupture is discovered, and this escaping gas is, of course, a fire hazard. Adequately sized safety valves, piped to discharge away from the unit if possible, are considered the highly preferable means of protecting the plant from excess pressure.

Cycle Time

Within the limits of the heat available and cooling time required, an operator may vary the length of adsorbing cycles for maximum product extraction. When these units were initially introduced, one of the questions most often asked concerned minimum cycle time, and whether the cooling cycle time could be shortened to the point where production was adversely affected.

Figure 1 represents a test on a two tower closed cycle unit, switching towers at 45-minute intervals. As can be seen, most of the product was produced by the end of the heating period, when the temperature of regeneration gas from the tower was only about 200°. Liquid production ceased completely about 7 minutes before the end of the cooling period. In this instance, the gas purchaser's limitation on the temperature of residue gas prevented any further shortening of the cooling period. Otherwise, an attempt would have been made to shorten the cycles in an effort to improve over-all extraction, particularly during periods when maximum gas volumes were being processed.

Performance Guarantees

Most manufacturers will offer performance guarantees of one type or another with their packaged units. Recognizing that there is almost always a variation between the composition of gas processed and the design analysis, it is considered preferable to have these guarantees based on recovering as liquid products a percentage of the desired components contained in the inlet gas, subject to variations in operating conditions and to a maximum production equal to the liquid capacity of the unit.

Most units tested have at least come close to meeting the guaranteed performance. However, it should be pointed out that present methods of gas sampling and analysis make it almost impossible to effectively challenge the extraction efficiency of a unit operating on lean gas if the extraction is reasonably close to the guaranteed performance.

For example, assume a gas with a tested normal pentane content of 0.14 mole percent (equal to 0.05 gpm) where recovery of this component is guaranteed to be 60 percent of the available content. If actual stock tank liquid analysis indicates that pentane recovery is only 0.025 gpm (50 percent) rather than the guaranteed .03 gpm, the plant is short almost 17 percent of the anticipated production. But have we proved that the unit is not performing as represented?

Perhaps—but if sampling and analysis of the inlet gas admits the possibility of an error as small as three hundredths of a mole percent, then the inlet gas could have a content as low as 0.11 mole percent, or 0.0393 gpm, and the unit has extracted 64 percent of the available pentane. While this is only one component of the total production, it illustrates the difficulty encountered in attempting to accurately evaluate the efficiency of units operating on lean gas streams.

Residue gas analyses are considered to be wholly unreliable because the cyclic nature of the unit yields a widely varying residue gas composition, making accurate sampling impossible.

Operating Records

Once a unit is in operation, the production offices will probably desire to receive routine reports to permit checking of operations. A simple form, prepared in the field and forwarded weekly, showing daily gas volume processed, inlet gas temperature, and daily production, and explaining any shutdowns or operating problems has proved effective, and does not burden field personnel with excessive paper work. The operating charts (showing temperatures and regeneration gas rates) can be forwarded with these reports. It has been found that the charts provide excellent indicators of operating irregularities, and in many cases the charts alone can pinpoint the cause of the difficulty.

A tabulation of operating problems reported has proved valuable as a means of identifying recurring difficulties in any particular unit.

Conclusions. In spite of the numerous possible problems which have been mentioned, the field operation of short cycle dry bed adsorption units will, after a relatively short period of service for each unit, becomes a routine matter requiring little attention other than the operating and maintenance time rendered by field personnel. Decreasing operating difficulties are logically the result of removing any bugs from the individual unit, and the increased experience gained by the operators actually handling the plant.

ACKNOWLEDGMENT

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About the Author

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Absorber Design—Fast Yet Rigorous

This graphical modification to the Kremser absorption calculation can be made in 2 to 3 hours. Operating data show it's accurate

Spencer H. Landes* and F. W. Bell
Brown & Root, Inc., Houston

THIS ABSORBER DESIGN method is a happy medium between a rigorous plate calculation and the shortest empirical method. The inexperienced or part-time absorption calculator should be able to design safely by this method.

This graphical method has been applied successfully to both high and low pressure absorbers, normal and sub-zero temperature absorbers, and reabsorbers for recovery of ethane and heavier hydrocarbons. Operating data substantiate the accuracy and adaptability of the method. With a little practice, the complete calculation can be made in 2 to 3 hours. Handy calculation forms are presented to speed up the calculations.

METHOD OUTLINE

Data. Equilibrium values for absorption oil systems have been studied by many researchers. Among the most popular data for heavy oil systems at atmospheric temperatures is that of Webber.[12] Composition of the liquid phase has a pronounced effect on component K values. Some authors have found it expedient to correct the methane K value for composition effect in heavy oil systems at atmospheric temperatures. In low temperature absorption where light oils are used, the phase compositions also have an effect on the propane K values. Correlations such as the Benedict Rubin-Webb[1] equation of state have been used successfully to give the effect of phase composition on equilibrium data. This correlation, in terms of molal average boiling point of each phase, does not always agree with K data taken from the NGSMA Data Book at the corresponding convergence pressure. The absorber operating conditions wherein composition exerts a great influence on equilibrium data, and indirectly, the absorber oil rate, will be discussed later.

Heat data for absorber heat balances should be selected with as much care as given to K data. We have found that more accurate heat balances are obtained by using a combination of heats of absorption for phase change and sensible heat for no phase change rather than using total enthalpies. For specific heats of gases we use a combination of Buthod's[2] curves and experimental data of Sage et al.[9] Specific heats of liquids obtained from various sources are usually in good agreement. Maxwell[4] and TEMA are good sources. Heats of absorption are more difficult to obtain. We have used the following: Scheibel[10] average molecular weight correlation; Peter's[8] extrapolated data correcting for liquid

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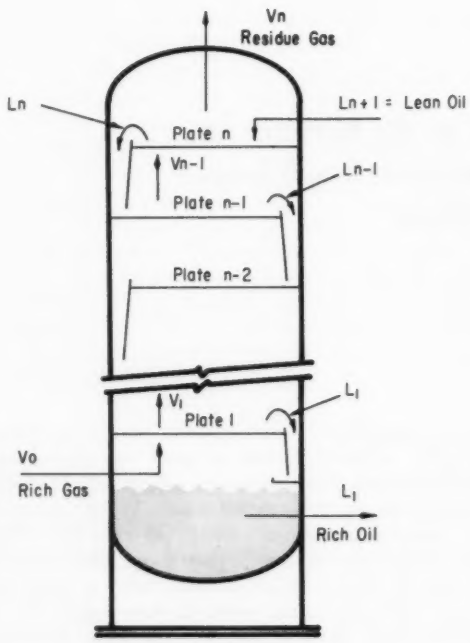
phase mole weight; Kellogg total heat charts that appear in the 1957 NGSMA Data Book. None of these will cover the full range of temperatures and high pressures encountered in absorption calculations. We have compiled heats of absorption for each hydrocarbon component by correcting zero pressure heats of vaporization for pressure using reduced properties and the $\Delta H/T$ correlation of Watson.[12] The reduced temperatures and pressures were those of a natural gas containing approximately 90 mole percent methane. Table 1 shows a comparison of the heats of absorption from the various sources mentioned above.

TABLE 1—Heats of Absorption BTU per Pound Mole

	C_1	C_2	C_3	C_4	C_5	C_6
100°	**500 psia**					
NGSMA 1957 (Kellogg)	....	3030	5240	6380	6080	....
NGSMA 1951 (Scheibel)	1280	3440	4450	....	....	....
Peters	1005	4200	4980	....	....	....
Brown & Root	1250	3500	5100	7700	8400	9200
100°	**1000 psia**					
NGSMA 1957 (Kellogg)	....	2640	4580	....	....	....
NGSMA 1951 (Scheibel)	1000	1560	....	....	....	....
Peters	....	....	....	....	....	....
Brown & Root	1000	2500	3800	5450	6200	7700
100°	**2000 psia**					
NGSMA 1957 (Kellogg)	....	1830	2950	....	....	....
NGSMA 1951 (Scheibel)	....	....	....	....	....	....
Peters	....	....	....	....	....	....
Brown & Root	550	1100	2050	2900	3700	4400



A Absorption factor for any component $= \frac{L}{VK}$

K Equilibrium coefficient for any component $= Y/X$

L Moles of liquid leaving any tray in absorber

T Temperature °F.

V Moles of vapor leaving any tray in absorber

X Mole percent of component in liquid phase

Y Mole percent of component in vapor phase

SUBSCRIPTS

o Rich gas to absorber

i Bottom tray of absorber

n Top tray of absorber

Calculation Method. The sample calculation given with this paper is based on a first trial separation calculated by the Kremser[6] method as modified by Souders-Brown.[11] The assumptions made in this calculation are the average temperature at which absorption takes place and the percent of equilibrium reached. The calculation is a rapid one when carried out on the form shown. It yields a trial oil rate and an off gas which are the starting points for the more rigorous calculations.

The residue gas from the first trial calculation is used to calculate the top tray of the absorber. Since the Souders-Brown empirical method usually gives a low oil rate, we arbitrarily boost the oil quantity by 10 percent prior to using it in the plate calculation. To calculate the top tray, one must assume the top temperature, run the dew point on the residue gas at this temperature, filling the void with absorber oil. The top temperature is checked by a heat balance around the top of the absorber assuming also a temperature of the vapor from the tray below. Note that we use sensible heat of the gas and oil and the ΔH of absorption for the mole weight of the hydrocarbon absorbed. If the calculated temperature does not check the assumed temperature, the calculation is repeated until a check is made.

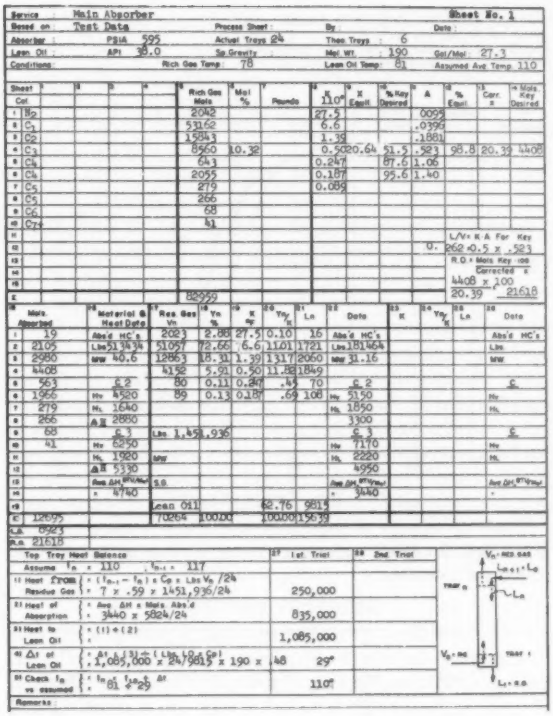
After the top tray is calculated, the tray below is calculated in the same manner. The assumption of the temperature on the tray below the top tray is verified by a two tray heat balance assuming a temperature of the vapor from the third tray from the top. One might say that we leave one assumption unchecked; otherwise, we would have to calculate all the way to the bottom tray in order to verify our gas temperature assumption. Actually, we can plot the lean oil, residue gas and rich gas temperatures and estimate the correct tray temperature to use.

To continue the calculation, we now run an over-all heat balance on the absorber to find the rich oil temperature. This will be the bottom tray temperature. The temperature profile is now plotted.

Now that we have the tower temperature profile, we proceed to calculate and plot the L/V ratio for each tray. The L/V ratio for the two top trays is obtained from the tray calculations. The bottom tray L/V is calculated by assuming that the shrinkage across the trays is equal between the bottom and the next to the top tray.

Sample Calculations on Handy Forms

1st Trial



Service: Main Absorber — Sheet No. 1

Based on: Test Data — Process Sheet: — By: — Date:

Absorber: PSIA 595 — Actual Trays 24 — Theo Trays: 6

Lean Oil: API 38.0 — Sp Gravity — Mol Wt: 190 — Gal/Mol: 27.3

Conditions: Rich Gas Temp: 78 — Lean Oil Temp: 81 — Assumed Ave. Temp 110

Sheet Cat.	Rich Gas Mols	Mol %	Pounds	K @ 110° Equil.	X Equil.	% Key Desired	A	% Equil.	Corr. x	Mols Key Desired
1 H_2	2042			27.5			.0055			
2 C_1	53162			6.6			.0392			
3 C_2	15943			1.39			.1881			
4 C_3	8560	10.32		0.520	20.64	51.5	.523	98.8	20.32	4408
5 C_4	643			0.247		87.6	1.06			
6 C_5	2055			0.107		95.6	1.40			
7 C_6	279			0.089						
8 C_7	266									
9 C_8	68									
10 C_{7+}	41									
11										
12							0.	L/V= K A For Key		
13								262 x .5 x .523		
14								R.G. Mols Key -100 Corrected x		
15								4408 x 100 / 20.39 = 21618		
16										
E	82959									

Mols Absorbed	Material Balance Heat Data	Res. Gas Vn	Yn %	X or Yn/K	Yn/K	Ln	Data	K	Yn/K	Ln	Data
19	Abs'd HC's	2023	2.88	27.5	0.10	16	Abs'd HC's				Abs'd HC's
2105	Lbs 51 34 74	51057	72.66	6.6	11.01	1721	Lbs 181464				Lbs
2980	MW 40.6	12863	18.31	1.39	13.17	2060	MW 31.16				MW
4408		4152	5.91	0.50	11.82	1849					
563	C_3	80	0.11	0.247	.45	70	C_3				C_3
1960	Mv 4520	89	0.13	0.107	.69	108	Mv 5150				Mv
279	M_L 1640						M_L 1850				M_L
266	ΔH 2850						3300				
68	C_3	Lbs 1,85,936					C_3				C_3
41	Mv 6250						Mv 7170				Mv
	M_L 1920	MW					M_L 2220				M_L
	ΔH 5330						4950				
	Ave $\Delta H_{60°F/Mol}$	S.G.					Ave $\Delta H_{60°F/Mol}$				Ave $\Delta H_{60°F/Mol}$
	= 4740						= 3440				=
		Lean Oil			82.76	9815					
12695		70264	100.00		100.00	15639					
8923											
21618											

Top Tray Heat Balance		1st Trial	2nd Trial
Assume t_n = 110	t_{n-1} = 117		
1) Heat from Residue Gas	= $(t_{n-1} - t_n)$ x Cp x Lbs V_n /24 = 7 x .59 x 1451,936/24	250,000	
2) Heat of Absorption	= Ave ΔH x Mols Abs'd = 3440 x 5824/24	835,000	
3) Heat to Lean Oil	= (1) + (2) =	1,085,000	
4) Δt of Lean Oil	= Δt / (3) ÷ (Lbs LO x Cp) = 2,085,000 x 24/9815 x 190 x .48	29°	
5) Check t_n vs assumed	= t_n = 81 + 29 Δt	110°	

Remarks:

Service: Main Absorber — Sheet No. 2

Based on: Test Data — Process Sheet: — By: S.H.L. — Date: 7-50

Temperature and L/V on Tray Below Top, t_{n-1} ℄ $(L/V)_{n-1}$

Sheet Cat.	V_n Mols	L_n Mols	V_{n-1} Mols	Y_{n-1} %	K @ 117°	Y_{n-1}/K	L_{n-1} Mols	Data	Heat Balance (Two Tray)
1 H_2	2023	16	2039	2.68	27.5	0.10	17	Abs'd HC's	Assume t_{n-1} = 117°
2 C_1	51057	1721	52778	69.36	6.7	10.35	1727	Lbs 227404	Heat from 1451936/24 x .59
3 C_2	12863	2060	14923	19.61	1.44	13.62	2271	MW 33.1	Res. Gas 117-110 = 250,000
4 C_3	4152	1849	6001	7.89	.53	14.89	2484		Heat of Absorption 6871/24 x 3450 = 985,000
5 C_4	80	70	150	0.20	.26	0.77	128		Δt of Lean Oil 1,235,000/24
6 C_5	89	108	197	0.26	.20	1.30	247		Lean Oil 9815 ÷190 x .48=33.2
7 C_6						.18	25		Calculated t_{n-1} 81+33.2 vs 117°
8 LO		9815				58.82	9815		$(L/V)_{n-1}$ = 0.22
E	70264	15639	76008	100.00		100.00	16605		

Bottom Tray Temperature (R.G. Temperature)

Assume Rich Oil Temperature, t_1 = 100

1) Heat to Residue Gas = $(t_n - t_a)$ x Cp x Lbs V_n = (110-78) x .59 x 1451936/24 = 1,140,000

2) Heat of Absorption = ΔH_{abs} x Mols HC = 4740 x 12695/24 = 2,500,000

3) Heat to Lean Oil = (2) − (1) = 1,360,000

4) Δt of Lean Oil = (3) ÷ [Lbs LO x Cp] = 1,360,000 ÷ 24/9815 x 190 x .48 = 36.5

5) Check t_1 vs assumed = t_1 = t_{LO} + Δt = 81 + 36.5 = 107.5 vs 100°

L/V on Bottom Tray = $(L/V)_1$:

Assume equal number mols gas absorbed each theo. tray except top.

solving for V_1, mols leaving bottom plate = $V_n - [(L_2 - L_n)$ / (Total Trays - 1)]

From Sheet: V_1 = Col. 8 − [(Col. 10 − Col. 11) / (Trays - 1)]

V_1 = 82959-(22510-15639)/5 = 81,588

$(L/V)_1$ = 22,510 / 81,588 = 0.276

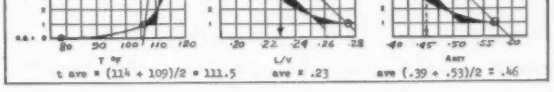
$(L/V)_a$ = 15,639/70264 = 0.223, A_n = .223/.50 = .445

$(L/V)_{n-1}$ = 0.22, A_{n-1} = .22/.51 = .433

$(L/V)_b$ = .276, A_1 = .276/.485 = .569

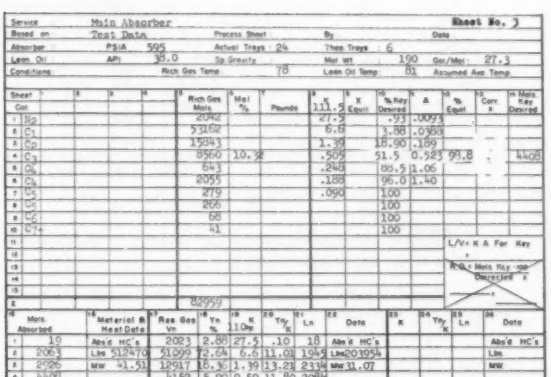
Trial II Lean Oil = 9815 (Assay / Avg.) = 9815 (0.523 / 0.46) = 11,100

Graphical Solution For Average Absorption Factor For Key



t ave = (114 + 109)/2 = 111.5 — ave = .23 — ave (.39 + .53)/2 = .46

2nd Trial



Service: Main Absorber — Sheet No. 3

Based on: Test Data — Process Sheet: — By: — Date:

Absorber: PSIA 595 — Actual Trays 24 — Theo Trays: 6

Lean Oil: API 38.0 — Sp Gravity — Mol Wt: 190 — Gal/Mol: 27.3

Conditions: Rich Gas Temp: 78 — Lean Oil Temp: 81 — Assumed Ave Temp

Sheet Cat.	Rich Gas Mols	Mol %	Pounds	K @ 111.5° Equil.	X Equil.	% Key Desired	A	% Equil.	Corr. x	Mols Key Desired
1 H_2	2042			27.2			.751	.0093		
2 C_1	51162			6.6			1.38	.0350		
3 C_2	15943			1.39			18.90	.189		
4 C_3	8560	10.32		.505		51.5	0.523	99.8		4408
5 C_4	643			.248		88.5	1.06			
6 C_5	2055			.188		96.0	1.40			
7 C_6	279			.090		100				
8 C_7	266					100				
9 C_8	68					100				
10 C_{7+}	41					100				
11								L/V= K A For Key		
12								R.G. Mols Key -100 Corrected x		
13										
14										
15										
E	82959									

Mols Absorbed	Material Balance Heat Data	Res. Gas Vn	Yn %	K @ 110°F	Yn/K	Ln	Data	K	Yn/K	Ln	Data
19	Abs'd HC's	2023	2.88	27.5	.10	18	Abs'd HC's				Abs'd HC's
2063	Lbs 512470	51099	72.64	6.6	11.01	1945	Lbs 203954				Lbs
2826	MW 41.51	12917	18.36	1.39	13.21	2334	MW 31.07				MW
4408		4152	5.90	0.50	11.80	2084					
529	C_3	74	.10	.247	.40	70	C_3				C_3
1973	Mv 6220	82	.12	.107	.64	113	Mv 7070				Mv
279	M_L 2100	"		.089			M_L 2170				M_L
266	ΔH 1120						4900				
68	C_3						C_3				C_3
41	Mv 4520	Lbs 1453474					Mv 5120				Mv
	M_L 1800	MW 20.66					M_L 1820				M_L
	ΔH 2720						3300				
	Ave $\Delta H_{60°F/Mol}$	S.G. .712					Ave $\Delta H_{60°F/Mol}$				Ave $\Delta H_{60°F/Mol}$
	=						= 3430				=
		L.O.			82.84	11100					
12345		70347	100.00		100.00	17664					
11100											
23445											

Top Tray Heat Balance		1st Trial	2nd Trial
Assume t_n = 108	t_{n-1} = 114		
1) Heat from Residue Gas	= $(t_{n-1} - t_n)$ x Cp x Lbs V_n = 6 x .59 x 1453373/24	213,000	
2) Heat of Absorption	= Ave ΔH x Mols Abs'd = 3430 x 6564/24	926,000	
3) Heat to Lean Oil	= (1) + (2) =	1,141,000	
4) Δt of Lean Oil	= Δt = (3) ÷ (Lbs LO x Cp) = 1141000 x 24/11100 x 190 x .48	27°	
5) Check t_n vs assumed	= t_n = t_{LO} + Δt = 81 + 27	108°	

Remarks:

Service: Main Absorber — Sheet No. 4

Based on: — Process Sheet: — By: — Date:

Temperature and L/V on Tray Below Top, t_{n-1} ℄ $(L/V)_{n-1}$

Sheet Cat.	V_n Mols	L_n Mols	V_{n-1} Mols	Y_{n-1} %	K @ 112°F	Y_{n-1}/K	L_{n-1} Mols	Data	Heat Balance (Two Tray)
1 H_2	2023	18	2041	2.65	27.5	.10	20	Abs'd HC's	Assume t_{n-1} = 114°
2 C_1	51099	1945	53044	69.27	6.6	10.45	2040	Lbs 276114	Heat from 2 x .59 x 1453474/24 = 71,500
3 C_2	12917	2334	15251	19.85	1.39	14.27	2785	MW 30.80	Res. Gas
4 C_3	4152	2084	6236	8.11	.505	16.06	3134		Heat of Absorption 3560 / 24 = 1,260,000
5 C_4	74	70	144	.19	.248	.77	1450		Δt of Lean Oil 1331,500 x 24 / 11,100 x 190 x .48 = 21.8°
6 C_5	82	113	195	.25	.188	1.33	260		Lean Oil 9815 + 1325 = 11,140
7 C_6						.15	29	5150	Calculated t_{n-1} 81+21.8 = 102.8 vs 108°
8 LO						56.87	11,100	11100	$(L/V)_{n-1}$ = 0.259
E	70347	6564	76911	100.00		100.00	19310	16464	

Bottom Tray Temperature (R.G. Temperature)

Assume Rich Oil Temperature, t_1 = 105°

1) Heat to Residue Gas = $(t_n - t_a)$ x Cp x Lbs V_n = (108-78) x .59 x 1453474/24 = 1,070,000

2) Heat of Absorption = ΔH_{abs} x Mols HC = 2870 x 12346/24 = 1,990,000

3) Heat to Lean Oil = (2) − (1) = 920,000

4) Δt of Lean Oil = (3) ÷ [Lbs LO x Cp] = 920,000 ÷ 24/11,100 x 190 x .48 = 21.8°

5) Check t_1 vs assumed = t_1 = t_{LO} + Δt = 81 + 21.8 = 102.8 vs 105°

L/V on Bottom Tray = $(L/V)_1$:

Assume equal number mols gas absorbed each theo. tray except top.

solving for V_1, mols leaving bottom plate = $V_n - [(L_2 - L_n)$ / (Total Trays - 1)]

From Sheet: V_1 = Col. 8 − [(Col. 10 − Col. 11) / (Trays - 1)]

V_1 = 82,959-(23446-17664)/5 =

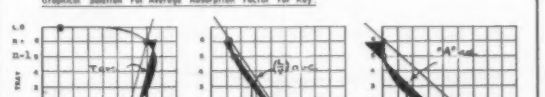
$(L/V)_1$ = 23446 / 81799 = 0.287

$(L/V)_a$ = 17664/70347 = 0.251, A_n = .251/.50 = .502

$(L/V)_{n-1}$ = 19518/76911 = 0.255, A_{n-1} = .255/.505 = .505

$(L/V)_b$ = , A_1 = .287/.47 = .61

Graphical Solution For Average Absorption Factor For Key



Temperature Profiles

The shaded area on the curves is the graphical averaging step for a curved line. Shaded area above curve should equal that below the curve.
The straight line is located by trial and error until shaded areas are "eyeballed" equal. Note that the averaging reference line is drawn parallel to dotted line connecting top and bottom tray.

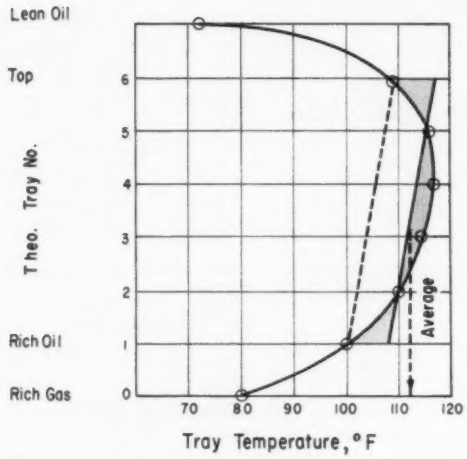


FIGURE 1—Normal for medium pressure absorber.

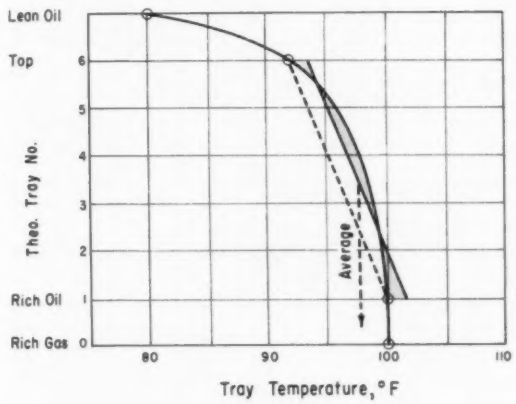


FIGURE 2—High pressures flatten curve as in this 2,000 psi absorber.

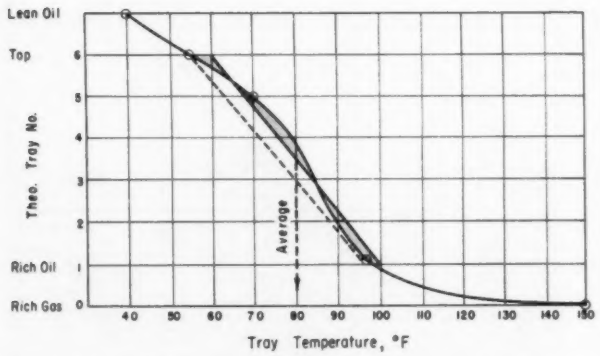


FIGURE 3—Reabsorber of rich oil demethanizer can be entirely different.

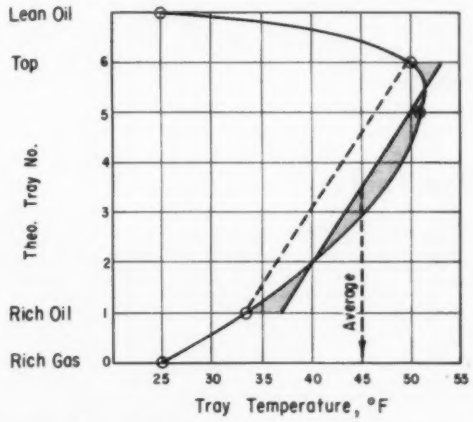


FIGURE 4—Refrigerated absorber without presaturation or intercooling.

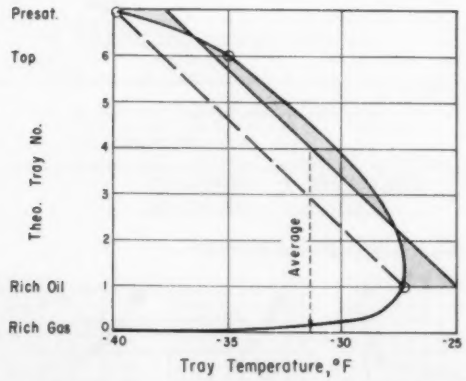


FIGURE 5—Low temperature absorber with presaturator chiller.

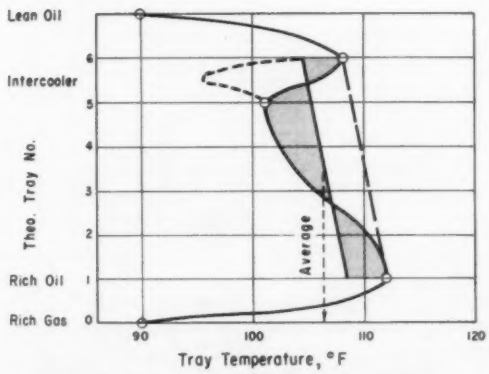


FIGURE 6—A typical intercooled absorber.

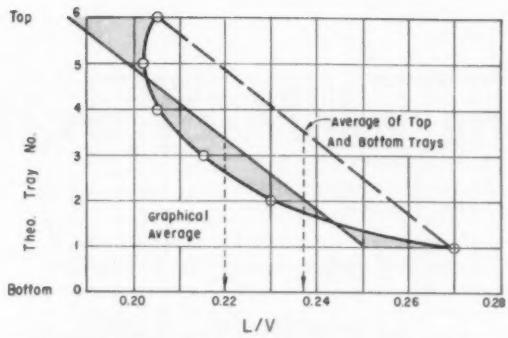


FIGURE 7—Liquid/vapor on each tray of a medium-pressure, atmospheric-temperature absorber.

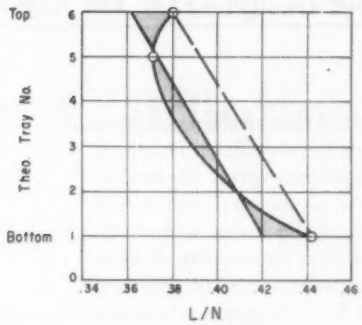


FIGURE 8—Liquid/vapor on each tray of intercooled absorber.

The absorption factor for the key component may now be calculated using the L/V and K values obtained from the above plate calculations. Plot the absorption factor versus the plate number. The absorber average A_{key} is obtained by graphically averaging the plot. If the calculated average absorption factor is widely variant from the required absorption factor, the oil rate should be adjusted and the procedures repeated using previous trial temperature. A sample calculation is shown in the four calculation sheets.

DESIGN FEATURES

Temperatures. The rigorous steps to arrive at the two top plate temperatures may appear tedious; however, the need for accurate temperatures is apparent if one considers that the top temperature is the starting point for the over-all heat balance, the L/V, and the absorption factor calculation. To emphasize this more strongly, let us review some typical absorber temperature profiles.

A great variety of temperature profiles are possible. The normal profile expected for medium pressure, atmospheric temperature absorption is as shown in Figure 1. The effect of high pressures is to flatten the curve as in Figure 2, for 2,000 pound absorption. The reabsorber of a rich oil demethanizer may exhibit an entirely different profile, Figure 3. A refrigerated absorber operating without presaturation or intercooling may have a profile as in Figure 4. Figure 5 is typical of a low temperature absorber with a presaturator chiller. The top temperature is selected and the chiller and separator are calculated as the top theoretical tray. To calculate the heat balance on the chiller, the temperature of the gas from the absorber must be known and is obtained by calculation and plotting the profile as described above. A large part of the over-all heat of absorption is removed by the chiller and thus accounts for the small temperature rise on the top tray.

By using the design method, the location of an intercooler and the temperature of the rich oil to the intercooler can be determined with reasonable accuracy. A typical temperature profile of an intercooled absorber is shown in Figure 6.

Liquid and Vapor Rates. The liquid-vapor ratio profiles are as important as temperature profiles in analyzing absorber calculations. Figure 7 is an example of L/V ratios on each theoretical tray of a medium pressure, atmospheric temperature absorber. It can be seen readily that averaging the L/V of the top and bottom trays will always result in a larger L/V than that obtained by averaging the whole tower.

The various benefits of knowing the liquid and vapor rates leaving any tray in an absorber are assessed as follows:

1. When a large gas shrinkage is expected in an absorber, knowledge of the liquid-vapor ratio speeds up the final absorption calculation by reducing the number of trials required.
2. For intercoolers, L/V ratio plots are helpful in specifying the heat exchange equipment. The intercooler does not effect the L/V profile as severely as it does temperature profile (compare Figure 6 to Figure 8).

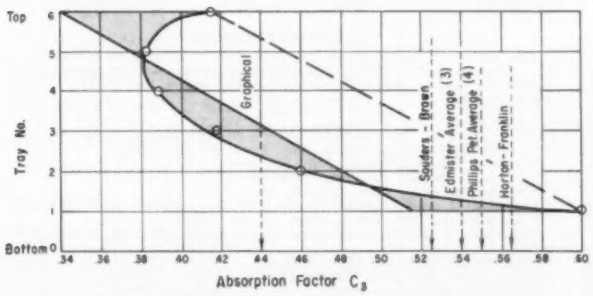


FIGURE 9—Comparison of average absorption factors by different calculation methods.

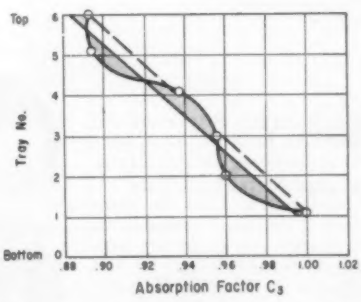


FIGURE 10—Absorption factor profile for intercooled absorber.

Profile of Absorption Factors. The plot of the absorption factor for each component versus theoretical tray number is a visual evidence of what part of the tower is most effective for that component. A typical absorption factor profile is shown in Figure 9 for a medium pressure absorber. This profile was obtained from tray calculations based on performance test data. We have also plotted the average absorption factor for the key component as calculated by various published methods. In all the published methods that we compared, the calculated oil rates would be 10-20 percent below the actual oil rate required for the desired recovery of the key component.

Figure 10 is a plot of the absorption factor profile for an intercooled absorber.

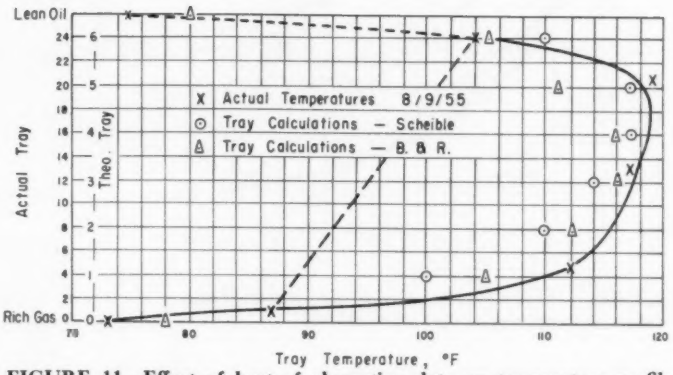


FIGURE 11—Effect of heat of absorption data on temperature profile in medium pressure absorber.

CONTINUING PROBLEMS

There is a lack of published data for light oil systems operating at sub-zero temperatures. To show the variation in oil rate and methane absorption that may be expected, a calculation was made on a 100 mole weight oil system with —40° inlet gas and oil. In one calculation, NGSMA K's were used. In the second calculation, K's were obtained from Kellogg Polyco charts. A 2,100 psia convergence pressure was selected for the NGSMA K's. The Kellogg MABP's were calculated using trial top and bottom plate compositions. The results are compared in Table 2.

TABLE 2—Effect of Equilibrium Values on Methane Absorption and Oil Rate at —30° F and 850 PSIG

	NGSMA K	Kellogg MABP K
Methane K	1.9	2.22
Propane K	0.105	0.11
Cl in Rich Oil moles	4440	3800
Lean Oil moles	3100	4200

Obviously the lean oil rate and recompression requirements will vary widely with K values. The use of a higher methane K will reduce the methane absorption. The oil rate is dependent on both the methane and propane Ks.

In addition to the equilibrium problems, there are enthalpy problems. A program is now in progress to correlate the heat of absorption data at high pressures by calculation and comparison with available operating data. One of the difficulties, in addition to accurate sampling and analysis of exit streams, is the effect of composition on heats of absorption. Since this is a task of monumental proportions, we shall only show the effect of heat data on calculated temperatures at a medium pressure of 600 pounds. The observed temperatures are plotted as a control in Figure 11. It appears that the bottom actual tray of an absorber may serve more as a heat transfer zone than a mass transfer stage.

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How to Make and Use C_4 Olefins

Part 1: 1-Butene and 2-Butene

Part 2: Isobutylene

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IN THE PREVIOUS ARTICLE[1] in this series concerning the C_4 olefins, it was noted that the normal butenes (1-butene, *cis*-2-butene and *trans*-2-butene) had similar chemical properties and, frequently, their reactions even lead to

$$CH_3$$
$$|$$

the same product. Isobutylene, $CH_3C{=}CH_2$, differs markedly from the *n*-butenes in its chemical properties and uses. It is characterized by the variety of reagents with which it will react, the mild conditions necessary to effect these reactions, and the lack of industrial utilization of the resulting compounds. With very few exceptions these reactions are additions to the carbon-carbon double bond to give a tertiary butyl derivative.

About 95 percent of the isobutylene utilized by the chemical industry is used to produce diisobutylene, trimers, butyl rubber, and other polymers. The other 5 percent represents a number of different compounds (Figure 4) which are used as antioxidants in foods, packaging, food supplements and in plastics. These applications, and especially the increased production of butyl rubber, should continue to contribute to a steadily increasing consumption of isobutylene.

PRODUCTION

Isobutylene is obtained from refinery streams and similar sources by its absorption in 65 percent sulfuric acid at about 15° C. The copresent *n*-butenes are not absorbed by sulfuric acid of this concentration. The isobutylene is regenerated by steam treatment of the acid extract and recovered as nearly pure isobutylene (Figure 5). There is now commercially available 99+ percent isobutylene. Figure 6 gives the recent production data.

UTILIZATION

The chemical utilization of isobutylene, as with the *n*-butenes, is conveniently divided into reactions which lead to individual compounds and those which produce polymers.

Chemical Derivatives

Hydration—*tert*-Butyl Alcohol. Isobutylene reacts with sulfuric acid about 200 to 400 times faster than 1-butene or 2-butene. Because of this greater reactivity, 50-65 percent sulfuric acid at 10°-30° C is used in its hydration. Under these conditions the main product is *tert*-butyl alcohol with only a relatively small amount of *tert*-butyl hydrogen sulfate being formed. The alcohol is readily dehydrated to isobutylene; thus, it must be isolated from very dilute acid or from a neutral solution. If the sulfuric acid is neutralized by ammonia, the resulting ammonium sulfate may be recovered.

Addition of Acetic Acid—*tert*-Butyl Acetate. *tert*-Butyl acetate (**TBA**) is a recently developed supplementary synergistic high level octane improver. It is

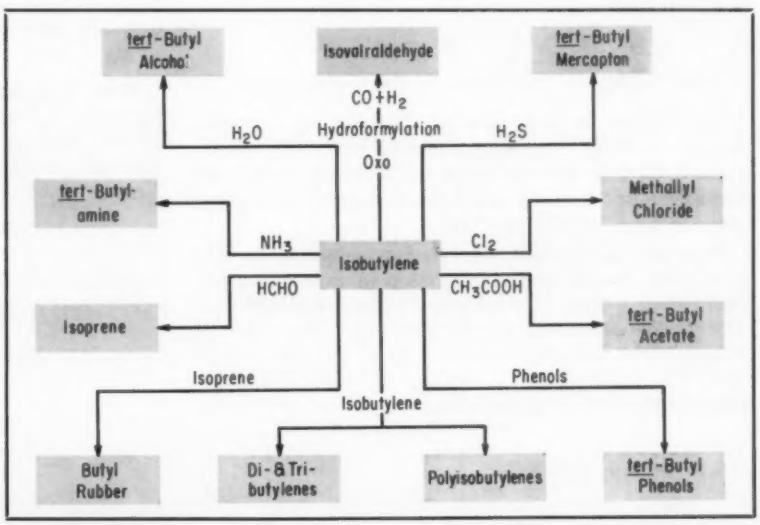


FIGURE 4—The actual and potential chemical utilization of isobutylene.

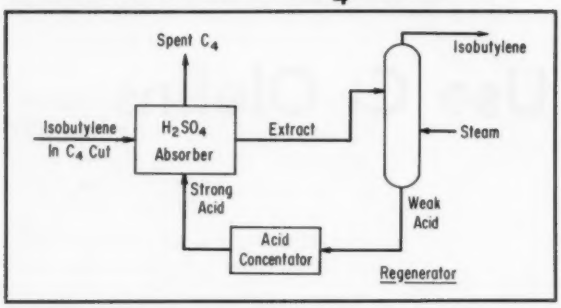


FIGURE 5—Here's how dilute sulfuric acid (65 percent) can be used to extract isobutylene from refinery butane-butylene streams.

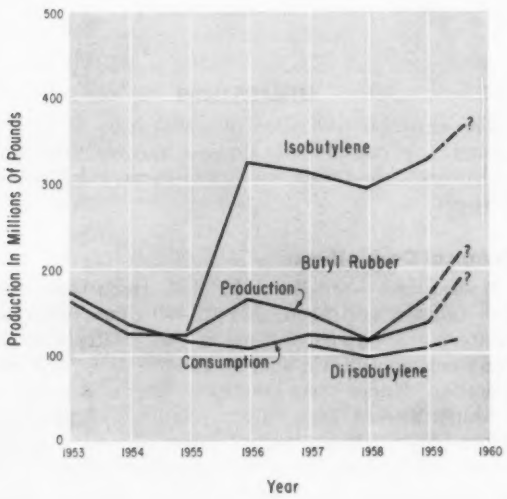


FIGURE 6—Production of isobutylene and diisobutylene are shown in relation with production and consumption of butyl rubber.

produced by the reaction between isobutylene and glacial acetic acid.

$$CH_2{=}C(CH_3){-}CH_3 + CH_3{-}C(=O){-}OH \rightarrow CH_3{-}C(=O){-}O{-}C(CH_3)_3$$

When sulfuric acid is used as the catalyst, an equilibrium is set up containing about 65 percent *tert*-butyl acetate. Certain solid catalyst are reported to give an almost quantitative yield. Relatively impure isobutylene may be used for this reaction.

Hydroformylation (Oxo)—Isovaleraldehyde. The conditions for the hydroformylation of isobutylene are essentially the same as those used for the *n*-butenes[2]—*ca.* 175° C, 200 atms. and a cobalt catalyst.

$$CH_2{=}C(CH_3){-}CH_3 + CO + H_2 \xrightarrow{Co_2(CO)_8} CH_3{-}CH(CH_3){-}CH_2{-}CHO + CH_3{-}C(CHO)(CH_3){-}CH_3$$

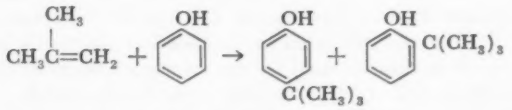
The alcohols resulting from the hydrogenation of the initial products (isovaleraldehyde and neopentylaldehyde) are reported to be 95 percent isoamyl alcohol and 4 percent neopentyl alcohol.[3] Chromatographic analysis of the crude reaction mixture has indicated the presence of 15 compounds with concentrations greater than 0.1 percent.[4] It was not possible, however, to resolve either the isovaleraldehyde-neopentylaldehyde peak or the isoamyl alcohol-neopentyl alcohol peak.

Alkylation. Isobutylene can be used to alkylate paraffin hydrocarbons containing a tertiary hydrogen atom (isobutane) and various aromatic compounds. The reaction with isobutane gives 2,2,4-trimethylpentane (isooctane).

$$CH_2{=}C(CH_3){-}CH_3 + CH_3{-}CH(CH_3){-}CH_3 \rightarrow CH_3{-}C(CH_3)_2{-}CH_2{-}CH(CH_3){-}CH_3$$

Isooctane is used as a reference fuel and a component in gasoline to increase its octane number. It is not used at the present time by the petrochemical industry.

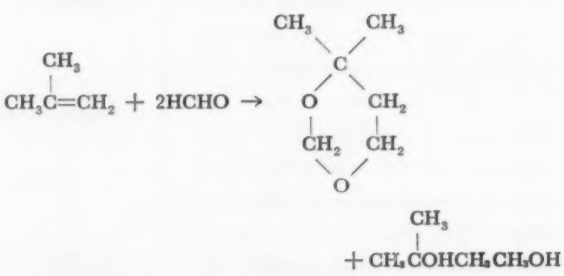
The alkylation of phenols to produce *tert*-butylphenols is catalyzed by mineral acids (preferably sulfuric acid) although anhydrous metal salts, boron trifluoride and similar compounds may be used.



The tertiary butyl group usually goes to the para position, especially at relatively high temperatures. Compounds of this type are intermediates for oil soluble phenol-formaldehyde resins, bactericides, and antioxidants. The oxidation inhibitor, 2,6-di-*tert*-butyl-4-methylphenol may be prepared by the use of an ion exchange resin.[5]

tert-Butylbenzenes may be produced by alkylation with isobutylene in the vapor phase over a supported phosphoric acid catalyst. *p-tert*-Butyltoluene is produced by alkylating toluene. It is oxidized to the corresponding *p-tert*-butylbenzoic acid which has been proposed as a vegetable oil "upgrader" in surface coating applications of alkyd resins.

Prins Reaction—Isoprene. The condensation of isobutylene with formaldehyde in the presence of aqueous mineral acids as catalysts (Prins Reaction) yields 4,4-dimethyl-1,3-dioxane as the principal product and 3-methyl-1,3-butandiol as a by-product.[6]



Various acid catalysts may be used, but the best results are reported to be obtained by the use of sulfuric acid

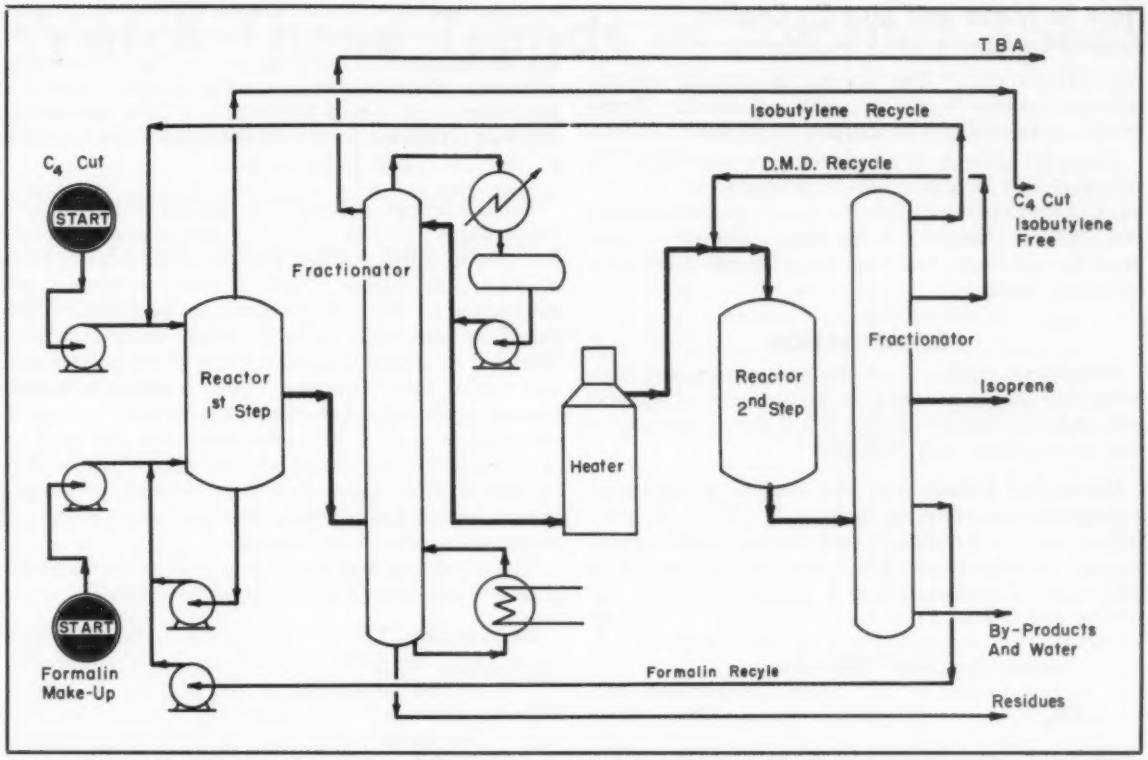
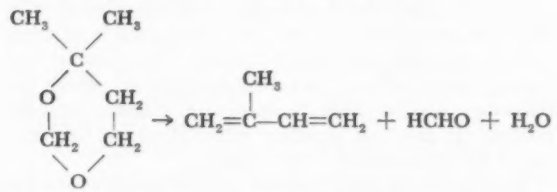


FIGURE 7—A method for making isoprene from isobutylene and formaldehyde.

at 25 to 40° C.[7] The isobutylene may contain other non-tertiary olefins because under the mild conditions used, they will not react.

The second step in the production of isoprene by this process is the catalytic decomposition of the dioxane to isoprene, formaldehyde and water.



Various catalysts may be used to effect this reaction both in the liquid and vapor phase—the vapor phase reaction is preferred. One patent claims a 64-70 percent yield at 220-240° C in the presence of monosodium phosphate or butylamine hydrogen phosphate deposited on graphite.[8] Apparently more efficient catalysts have been developed, however, because of a reported isoprene yield of 75.7 percent based on formaldehyde and 83.3 percent based on isobutylene.[9] This equates to 0.6 pound of formaldehyde and 1 pound of isobutylene per pound of isoprene. The over-all reaction is

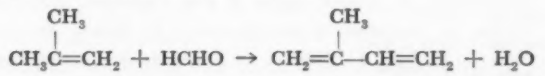
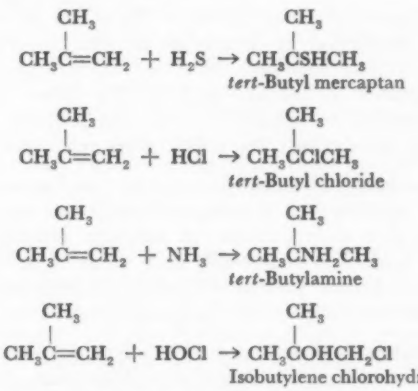
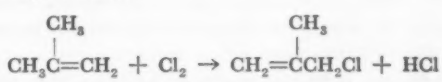


Figure 7 gives a schematic representation of this process for the production of isoprene from isobutylene and formaldehyde.

Miscellaneous Addition Reactions. A number of simple molecules will add to isobutylene to give *tert*-butyl derivatives. The following equations represent some of these reactions which are potentially, and some actually, of industrial importance.



Chlorination—Methallyl Chloride. The reaction of chlorine with *n*-olefins at low temperature is exclusively one of addition to give the corresponding olefin dichlorides. Isobutylene is unusual in that it reacts with chlorine under similar condition to give a substituted olefin —methallyl chloride.



The conditions are mild (0-150° C) and the yields are

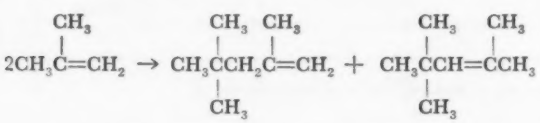
high (87 percent).[10] The principal by-products are isobutylene chloride (6 percent), isocrotyl chloride (3 percent) and unsaturated dichlorides (2 percent).

Methallyl chloride is commercially available and its suggested uses include synthesis of monomers, co-polymers, insecticides, fungicides, fumigants, pharmaceuticals and aromatic chemicals. It has both a reactive halogen atom for metathesis reactions and a double bond with enhanced reactivity.

POLYMERIZATION

Isobutylene readily forms dimers, trimers, and high molecular weight polymers in the presence of mineral acid and Lewis acid catalysts. It will also co-polymerize with other olefins and diolefins.

Dimers and Trimers. The first attempts to polymerize isobutylene were made by Butlerov in 1873.[11] He used sulfuric acid as the catalyst and obtained a mixture of di- and triisobutylenes. The same general process is still in use. The dimerization is brought about by absorbing isobutylene in 60-65 percent sulfuric acid at 10-20° C. The temperature is then raised to 80-100° C and maintained for about thirty minutes.



Yields of the polymer of about 90 percent are reported with a ratio of dimer to trimer of 4 to 1. The ratio of 2,4,4-trimethyl-1-pentene to 2,4,4-trimethyl-2-pentene is likewise 4 to 1. The commercial product has a boiling range of 99 to 104° C. The annual production of diisobutylene is approximately 100 million pounds (Figure 6).

The principal chemical use of the dimer mixture is in the production of detergents by the alkylation of phenol. It has also been used for the production of nonyl alcohol by the oxo process. The dimers can be depolymerized to isobutylene and this property limits their use to relatively low temperature reactions.

Isobutylene Polymers. Isobutylene can be polymerized by catalysts such as boron trifluoride and aluminum chloride to a wide spectrum of polymers ranging from viscous liquids to semi-solids and solids. The viscous liquids are called "polybutene" while the semi-solid and solid polymers are called "polyisobutylene".

Polybutene is produced by the polymerization of isobutylene dissolved in chloroform. Aluminum chloride is the catalyst and hydrogen chloride is used as an activator.[12] A process utilizing a refinery gas stream is available.[15] The average molecular weight of the products varies from 660 to 1,500 and the viscosity of the polymers varies from 100 to 20,000 SSU at 210° F. The temperature at which the polymerization takes place controls both the viscosity and the molecular weight of the polymer. The lower the temperature, the higner the molecular weight.

Polybutene is highly saturated and has high stability toward depolymerization. It is not attacked by oxygen or ozone and does not harden, set or "dry" on storage or in use. Its important industrial applications are in the manufacture of caulking and sealing compounds, adhesives, vibration dampers, surgical tapes, electrical insulations, and special lubricants. A 1958 production of about 30 million pounds of polybutene was reported by the U.S. Tariff Commission.

Polyisobutylene polymers are produced by the low temperature (—15 to —65° C.) polymerization of isobutylene in a hydrocarbon diluent using catalysts such as aluminum chloride. Their physical properties are determined by the polymerization temperature and vary from soft, sticky gums to tough, elastic materials. They have the same general stability of the polybutenes and similar uses. They are highly resistant to ozone, oxygen, acids and other chemicals and have very good electrical properties. Polyisobutylenes are also used as tackiness agents for oils which are required not to drip or splatter from bearings and as viscosity index improvers for oils and hydraulic fluids which are subjected to severe changes in temperature.

The chemistry and technology of polyisobutylene polymers has been reviewed by Michalowska.[13]

Butyl Rubber. The low temperature (—98° C) catalyzed ($AlCl_3$ or BF_3) copolymerization of isobutylene (97-98 percent) and isoprene (2-3 percent) in methyl chloride produces a solid rubber-like vulcanizable polymer.[14] This butyl rubber has the desirable properties of polyisobutylene without most of its undesirable characteristics. It is a general purpose rubber with unusually low gas permeability. Because of this property one of its earliest uses was in the production of tire inner tubes. In general it is used where air retention, high temperature stability or ozone and aging resistance is of importance. In 1959 tire tubes and pneumatic bags represented the largest market for butyl rubber followed by automotive mechanical goods and wire and cable uses.

The development of chlorine containing butyl polymers has remedied the inherent incompatible of butyl rubber with **SBR** and natural rubber. The chlorine containing butyl rubber is used in applications where flex resistance and/or high temperature stability are important. It also has superior rebound properties compared to conventional butyl rubber.

The future of butyl rubber lies in butyl tires. The inherent problems of heat build-up and low abrasion resistance apparently have been solved and butyl rubber tires are now on the market. Tires represented the fourth largest use of butyl rubber in 1959.

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Watch These Trends in Asphalt Specs

Here are important trends in paving asphalt specifications which more accurately reflect the desired engineering properties

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PAVING ASPHALT specifications evolution has reached a point where it is no longer possible to meet quality requirements with many asphalt bearing crude oils when refining is limited to common distillation methods. This trend toward more restrictive specifications is continuing as research reveals a more complete understanding of chemical and physical properties having an important bearing upon asphalt quality.

Refining methods and manufacturing specifications are being influenced substantially by current developments in asphalt technology.

The discussion which follows will: (1) Highlight areas where our technical knowledge is sufficient to substantiate desirable specification revision in the near future; and (2) predict the probable trend in specifications to cover important asphalt properties that still are not completely understood.

ASPHALT PROPERTIES PERTINENT TO PERFORMANCE

Properties required of a bituminous pavement binder to obtain the workability and durability properties desired by the user have been expressed in many scientific and pseudo-scientific ways. When stripped of all this technical complexity, performance requirements can be stated rather simply. To give superior performance a paving asphalt must:

1. Coat and adhere readily to mineral aggregate.

2. Provide a cohesive bond between mineral particles, and a bond which develops quickly.

3. Resist displacement by water and other displacing forces (i.e., gravitational or mechanical forces).

4. Resist embrittlement and other aging influences.

5. Be safe to handle under proper conditions of use.

6. Be uniform in characteristics from one delivery to the next, and uncontaminated with foreign materials.

Product uniformity from delivery to delivery can be fully as important to quality of the final pavement as any of the other requirements listed. However, uniformity, in itself, is not a physical or chemical property; so it will not receive detailed consideration in this discussion. Product uniformity can be controlled to some extent by tolerances permitted within specification limits. Uniformity depends, also, upon the supplier's desire to market a product of constant composition and properties (i.e., to control manufacture to a narrow band within specification limits).

With the exception of uniformity, all of the desired performance properties listed above are related to, or can be described in terms of, the following physical and chemical properties:

1. Consistency (viscosity)
2. Polar Character (electrochemical properties)
3. Rheological Character (colloidal properties)
4. Chemical Reactivity
5. Volatility(molecular weight properties)
6. Freedom from Contamination.

These are fundamental chemical and physical characteristics that should be amendable to measurement. These are the properties to which research attention is being directed in our efforts to improve asphalt quality specifications and to make specification limits directly meaningful. Considerable progress is being made along these lines.

CONSISTENCY

The penetration test at 77° F is probably the best known and most widely used test to measure paving asphalt consistency. This test has served well as a method for classifying various asphalt grades. However, 77° F is not a temperature of particular interest to highway engineers or to contractors. Instead they are interested in consistency properties as follows:

- In the region of 250°-325° F where pug mill mixing is carried out.
- In the region of 140°-160° F which is representative of maximum summertime pavement temperatures.
- In the region of 30°-40° F which is where pavement cracking due to brittleness is most likely to occur.

A group of asphalts that have the same consistency at 77° F as measured by the penetration test may have quite different consistency properties at any or all of the foregoing temperatures. Recently a number of agencies have adopted a high temperature viscosity specification requirement. Hence an important step has been made toward specifying a consistency requirement at a temperature of practical importance.

Viscosity Test. A temperaturee of 275° F is favored for measuring high temperature consistency. Since it is easily possible to measure paving asphalt viscosities on an absolute (kinematic) basis at 275° F, there seems to be no justification for reporting results on a Saybolt Furol basis, or any other empirical basis. It appears certain that kinematic viscosity at 275° F will find widespread use in paving asphalt specifications everywhere. This is an important step in the right direction as it permits consistency to be expressed in terms that can be comprehended easily by most engineers without their having to become asphalt technologists.

With capillary type viscometers presently available, precise measurement of kinematic viscosities of paving asphalts at temperatures in the region of 150°-180° F is feasible. Since 140° F is considered the ideal temperature for measurement of liquid asphalt viscosities, studies

are now in progress to confirm the suitability of present viscometers, or to develop new ones, which will permit measurement of kinematic viscosity of paving asphalts also at 140° F. This work shows promise of success. It seems likely that, within several years, kinematic viscosity at 140° F will replace penetration at 77° F as a specification requirement and probably also as a basis for expressing asphalt grade.

Except for the nostalgic aspects, this change should be welcomed by both asphalt producers and users. Kinematic viscosities conducted in a capillary viscometer will save a great amount of testing time and at the same time will provide a much more precise measure of consistency than the present penetration test is capable of.

Low Temperature Consistency. Precise measurement of paving asphalt consistency at near freezing temperatures poses a much more difficult problem. The penetration test, when conducted at these temperatures, is not very producible. Because of the high consistencies involved (upwards of 10^9 poises), special viscometers of the sliding plate type, concentric cylinder types, or the like, seem to be required. A substantial amount of research will be required to solve the problem of measuring kinematic viscosity at 30°-40° F with good precision and with equipment that is practical for use in laboratories normally concerned with asphalt testing. Perhaps for some time we will have to retain the penetrometer for measurement of consistency at cold temperatures, even though this instrument is supplanted by other apparatus for use at higher temperatures. Measurement of paving asphalt consistency in absolute units at low temperatures is a problem that merits considerable effort.

POLAR CHARACTER

One of the fundamental chemical properties that is responsible for the stickiness of asphalt and for its cohesiveness is sometimes referred to as "polar character." Chemical components commonly known as asphaltenes and resins are the fractions which give asphalt its distinctive character and differentiate asphalt from other

How Present Asphalt Specifications Were Derived

YEARS AGO when it appeared desirable to define asphalt quality by something more sophisticated than "It must be black and sticky," the natural move was to adopt some test limits on properties that were surmised to be important to performance. As is commonly the case, these test limits were fixed by analysis of certain asphalts that had exhibited satisfactory performance in use. Because residues from straight distillation were most economically available, and because many of these residues seemed to make excellent pavement binders, most asphalt specifications were built around these residues from relatively simple distillation processes. Attemps to build pavements from air blown asphalts, from residues derived from solvent extraction, or from blends of various residual materials met with varying success. Some of these products performed very well, indeed. Others failed miserably. The generally reliable performance of straight run residuums, compared to the undependable results obtained with other residual stocks, favored the adoption of specifications which define a straight run residuum. Hence, the die was cast.

Only by a slow step by step process have asphalt specifications progressed beyond this "straight run" era. In fact, even today some specifications specifically state that paving asphalts shall be produced by straight distillation methods only.

Air Blowing. Research in recent years has demonstrated that air blowing is not necessarily harmful to paving asphalt quality. The quality of some residual stocks is improved by air blowing. In other cases, air blowing can be quite deterimental to performance characteristics.

Solvent Extraction. The same can be said for solvent extraction processes. Propane de-asphalting, for example, is a feasible way of removing undesirable components from certain residual stocks to obtain good quality asphalts. Solvent processes presently are too costly to be of much practical importance but certainly they comprise a means for reconstituting residual components that could become more important in the future.

Additives: Use of additives to alter paving asphalt properties is another possible means for improving products of borderline quality or for making superior asphalts even better. Present specifications tend to discourage such practices even though they would be beneficial in some instances.

Spot Tests as Measure of Quality. When liquid phase thermal cracking became popular as a refining process, it was quite natural to look at thermally cracked residiuum as a potential pavement binder. Perhaps you are familiar with the high rate of embrittlement exhibited by many of the cracked asphalts that were tried in the 1930's. The Oliensis Spot Test proved to be a way of detecting most of these cracked components. Hence, it was adopted nearly everywhere as a specification requirement. It has since been proven that the spot tests of the Oliensis type are measures of colloidal stability properties. They do not measure either chemical reactivity or volatility, which are highly important contributors to asphalt embrittlement. Nevertheless, a spot test of some sort appears in virtually every paving asphalt specification in existence today. Even though producers and consumers generally recognize that spot tests will exclude some high quality asphalts and will pass certain asphalts that have consistently given unsatisfactory performance, user agencies are not willing to forego a spot test requirement until something better is offered in its stead.

A review of the history of paving asphalt specifications reveals that other specification requirements are based upon experiences and reasoning very similar to the background that supports present day use of spot tests as criteria of quality. Extensive research devoted to a better understanding of the fundamental nature of asphalt and to a better understanding of the physical and chemical processes involved in pavement failures has shown how present paving asphalt specifications can be improved. This technical process is providing information that ultimately should allow us to describe asphalts in terms of fundamentally important properties, rather than by methods indirectly related to quality as now practiced.

high molecular weight hydrocarbons. It is mainly these components that determine polar character.

The name "polar character" has been picked for want of a better term to denote certain properties that result from the distribution of electrical charges within the asphalt molecules. "Electrochemical nature" is another term used to express this property. Adhesivity, cohesivity, rate of wetting, color and other physical characteristics of asphalt are influenced to considerable extent by electrochemical properties.

Mineral aggregates have distinctive polarities, or electrochemical properties, of their own. Thus, the adhesive and cohesive properties of an asphalt are influenced greatly by the type of mineral aggregate employed in a paving mix. Upon contact with another polar surface, such as mineral aggregate or metal, the electrical charges on the asphalt molecules orient themselves in a more or less orderly fashion to increase the electrical attraction between the asphalt and the aggregate. Sometimes this is a relatively slow process, taking at least several weeks, because the so-called "continuous phases" of all asphalts are very high viscosity fluids which restrict the rate at which the polar molecules can move. This orientation is one of the reasons why "fresh" asphaltic mixes are softer (less cohesive) and more inclined toward water stripping than mixes that have "cured" for a time. Polar orientation seems to be as important as consistency with respect to the so called "rate of set" or "curing rate" of various paving asphalts.

Test Needed. The importance of polar character is generally recognized by asphalt technologists. However, we do not have any practical test procedure for measuring it that is suitable for inclusion in paving asphalt specifications. This property can be measured readily by techniques used in the research laboratory. For example, the Cohesiograph Test developed by the California Division of Highways for measuring liquid asphalt curing rates can be used also as an indirect measure of polar character of paving grade asphalts. A simpler test suitable for routine use in quality control laboratories is needed. As soon as such a test is developed, asphalt producers should expect specifications covering polar nature to be imposed.

A number of residuums now marketed as asphalt will not meet a reasonable specification covering polar nature. These are the asphalts that yield mixes of low cohesion and poor resistance to water action and abrasive effects of traffic, especially during the early life of the pavement.

COLLOIDAL PROPERTIES

Rheological character of asphalts has proved to be very complex. Asphalts are visco-elastic materials. The consistency they exhibit depends to some degree upon the rate at which they are sheared, upon the magnitude of stress imposed, or upon the history of the sample prior to testing. These deviations from true fluidity arise because asphalts possess a certain amount of gel structure.

The ductility test presently is employed widely as a way of separating gel type asphalts (low ductility) from those which have little gel structure. There has been a long standing belief that high ductility is indicative of good resistance to pavement cracking. That is, ductility has been considered a direct measure of resiliency properties. Many technologists believe that the ductility test provides an indirect measure of the ability for a paving asphalt to "re-heal" under traffic if fine cracks have developed due to excessive deflections while the pavement is at low ambient temperatures.

Documented field evidence to support the forgoing beliefs never has been developed, although several investigators have tried. It must be concluded that the ductility test should be replaced by a test method that measures gel properties of more fundamental importance than the properties responsible for either high or low ductility.

Most important is the fact that gel structure increases as a pavement ages. This is a contributory factor to undesirable pavement brittleness. This so-called "steric hardening" and thixotropy is the object of a great amount of research. We know that this mechanism of hardening involves physical adjustment of component molecules of the asphalt. The chemical makeup of the asphaltene resin, and oil components, together with time and temperature, determine the extent to which these physical adjustments take place.

Rapidly we are learning more about this type of hardening and how to minimize the undesirable aspects of it. Again our methods of studying these important rheological properties are by research tools that have not been adapted for use by quality control laboratories. Measurement of consistency (viscosity) at several conditions of shear provides a direct means for rating gel properties. However, until we can better define rheological properties and can clearly separate the desirable from the undesirable properties, new specifications pertaining to rheological characteristics will be poorly received. Nevertheless, much technical progress is being made and new specifications pertaining to rheological properties may be relatively close at hand.

CHEMICAL REACTIVITY

Any chemical reaction that a pavement binder undergoes during its service life is likely to change its physical properties and, hence, the performance properties of the pavement. The most important chemical reaction of concern is oxidation resulting from contact with atmospheric oxygen.

Oxidation of asphalt increases its consistency. As this embrittlement process continues, it eventually leads to pavement deterioration through cracking. Review of the literature covering research on asphalt quality shows that hardening of asphalt by exposure to air (or oxygen) has received extensive study and numerous methods have been proposed to measure oxidation resistance. So far, very few of these methods have been sufficiently simple (or correlated with observed performance) to make them of practical value.

Loss on Heating Test. Hardening that occurs in the Loss on Heating Test (ASTM D-6) results in part from oxidation but mainly from loss of the more volatile components. It is generally recognized that current specifications based upon the ASTM D-6 Loss on Heating (LOH) Test do not differentiate between asphalts of markedly different resistances to oxidation embrittlement. Probably this shortcoming arises because paving

asphalts are spread out in thin films in service whereas the LOH Test is concerned with the properties of asphalt in bulk.

Oxidation rate is controlled by rate of diffusion of oxygen into the asphalt. Hence, exposure of thin films to air brings forth a much different result than is obtained through exposure of a 50 gm sample in a three ounce can (ASTM D-6). Moreover, the oxidation process that occurs at 325° F has been found to be quite different than the oxidation mechanism involved at pavement temperatures (about 165° F maximum).

Thin Film Oxidation Test. Recently there has been a move toward the so-called Thin Film Oxidation (TFO) Test as a replacement for the Loss on Heating Test. This is a move in the right direction since the asphalt is spread into thinner films than formerly was the case. However, in the TFO Test, the asphalt film (about ⅛ inch thick) still is much thicker than the less than 10 micron films that prevail in a paving mix immediately after pug mill mixing.

Moreover, the TFO Test has retained the 325° F test temperature used for the LOH Test. This temperature is far removed from any temperature involved in service except for the temperatures employed during the hot-mixing and laying operations. As a matter of fact, TFO Test hardening measurements on a series of asphalts correlate quite well with the relative extent of hardening shown by the same asphalts during hot mixing operations.

It remains to be proven whether the TFO Test will rate relative hardening rates at pavement service temperatures. Laboratory and field studies to develop this answer are being conducted by several organizations at the present time. If a reasonable degree of correlation is found between TFO results and hardening rate in service, we should expect the TFO Test to become solidly entrenched in paving asphalt specifications for many years to come because of its simplicity. If, as a number of investigators predict, the TFO Test does not give a completely reliable guide to pavement embrittlement caused by oxidation (plus volatilization), eventually it will be superseded by a laboratory test that measures consistency increases when much thinner films are exposed to oxidizing conditions at temperatures in the range of maximum pavement temperatures.

Aging Test. The Shell Aging Index Test is an example of a thin film exposure that has shown good correlation with the relative embrittlement rates observed in service (even though the testing temperature of 225° F is somewhat higher than maximum pavement temperatures). This test demands test equipment and experimental techniques that are far more intricate and time consuming than desirable for routine quality control testing. Nevertheless, simplification of the present techniques is a distinct possibility. All asphalt marketers would be well advised to evaluate their products by embrittlement rate tests employing thin films (less than 10 microns) and moderate temperatures (not over 180° F). Products which harden rapidly under these conditions undoubtedly will be ruled out by future specifications.

VOLATILITY (MOLECULAR WEIGHT PROPERTIES)

Loss of the lightest asphalt fractions through volatilization is usually a minor contributor to hardening in service. However, some commercially used products containing low molecular weight components have been shown to harden substantially because of volatile loss. Hardening due to volatilization contributes to the results of the TFO Test. Volatilization also is a contributor to the hardening measured in tests which employ extremely thin films such as Shell's Aging Index. Hence, it is probable that the combined influence of volatility loss and chemical reactivity will be rated by a single thin film exposure test in future specifications.

Directionally, volatility is related to molecular weight. In asphalts that are not contaminated with light components or with surface active agents (e.g., silicones), flash point is an indication of molecular weight. Because of the pronounced influence of these contaminants, flash point is not a reliable measure of the extent to which hardening is likely to result through evaporation.

FREEDOM FROM CONTAMINATION (PURITY)

The only contaminants that are likely to find their way into paving asphalts are:

- Other petroleum residuums (e.g., other grades of asphalt products)
- Distillate petroleum products (e.g., Diesel fuel, or gasoline)
- Solid substances (e.g., dirt)
- Water.

Any appreciable contamination with other grades of

TABLE 1—Trends in Paving Asphalt Quality Tests

Basic Property	Typical Tests in Current Use	Tests Expected in Near Future	Probable Future Test Methods	Remarks
Consistency (Viscosity properties)	Penetration Viscosity at 275° F. Penetration ratio	Absolute vis. at 275° F. Absolute vis. at about 140° F.	Absolute vis. at about 40° F.	Absolute viscosities at 3 temperatures completely define consistency properties (excluding thixotropic effects).
Polar Character (Electrochemical properties)	None		Cohesiograph test (Calif.) or similar test	This property merits a great deal more study.
Rheological Character (Colloidal properties)	Ductility		Absolute vis. at various rates of strain	Research methods now available—must be simplified for practical use.
Chemical Reactivity	Loss on heating (% of penetration retained), Spot tests	Thin Film Oven Test (% loss and % penetration retained).	Aging Index (Shell) or similar test.	For practical use need more streamlined test than any now available—Aging Index Test should be simplified or possibly T.F.O. Test can be developed further.
Volatility (Molecular weight properties)	Loss on heating, Flash point			
Freedom from Contamination (purity)	Flash point, Solubility tests			No significant changes needed except that stirred type Flash Point test should be used.

asphaltic products will result in the product in question failing to meet one or more of the product quality specifications discussed previously.

Flash Point Test. Contamination with even small amounts of petroleum distillates, that could create a flammability hazard (or create a product deficiency), can be detected by a flash point test. A flash point test conducted in the right way provides a direct measure of fire hazard connected with the use of petroleum products. There seems to be little justification for replacement of the relatively simple flash point test with other tests to measure flammability hazards. However, there is good reason to favor a closed cup flash point test (such as the Pensky-Martens Test) over the open cup (e.g., Cleveland Open Cup) type of test that is in general use at present.

As mentioned before, exceptionally small quantities of surface active materials, such as silicone compounds, will greatly increase flash point temperatures when measurements are conducted in an unstirred vessel such as the Cleveland Open Cup apparatus. This flash point increase probably results from surface orientation of the surface active ingredient whereby diffusion and evaporation of light components are restricted. This quiescent surface condition does not necessarily prevail during the transporation and use of paving asphalts. This situation can be handled by use of a flash point test which provides continuous stirring. The abnormally low evaporation rate resulting from quiescent surfaces containing films of surface active materials is overcome by the stirring provided.

The foregoing findings favor a move toward adoption of the Pensky-Martens test for flash point. This test already has been adopted in some areas of the country, and this trend will continue.

The high temperatures involved in testing asphalts for flash point often cause a substantial amount of coke to form in the Kensky-Martens container. Removal of this coke is messy and time consuming. However, because the test is a good measure of flammability hazard, it seems unlikely that this troublesome feature will retard the trend toward its use. Perhaps someone will come forth with a simpler and more easily cleaned flash point apparatus that is just as reliable as the Pensky-Martens tester. If so, it will receive considerable support. There is no indication that such a possibility will be offered in the foreseeable future, however.

Solubility Tests. Other potential contaminants that might not show up in tests previously mentioned are solid substances. Examples are small amounts of dirt or other mineral matter, coke from refinery furnace tubes or scale from pipes used in transporting the asphalt. Contaminants of this type are detected readily by solubility tests using such solvents as carbon disulfide or carbon tetrachloride. Solubility tests will continue to be needed in asphalt specifications as a confirmation of product "purity."

Use of carbon disulfide as a solvent for this purpose should be discouraged because of its extremely flammable nature. Carbon tetrachloride or one of the related chlorinated solvents serve the purpose just as well. These chlorinated solvents do not present any toxicity hazard if they are used with proper ventilation such as a laboratory fume hood. It must be concluded that there is little justification for any change in the carbon tetrachloride solubility test now used so broadly in asphalt specifications.

Water. Whereas water is another potential contaminant, a separate specification to insure its absence does not appear necessary. Even a minute quantity of water will make itself apparent if it comes in contact with paving asphalt at usual storage and transportation temperatures (275°-450° F) or if it is present in cold asphalt which is then heated to these temperatures. Even though paving asphalt should become contaminated with small amounts of water, no harm is done to the quality of the product once the water has boiled away.

SUMMARY

Table 1 is a summary of the previous discussion. It attempts to chart a step-wise progression toward more meaningful specifications.

Paving asphalt specifications are being revised in many areas of the country. Quality minded producers would do well to keep abreast of these changes and be prepared to meet them. Indeed, producers should take a leading part in the development of new asphalt specifications to make sure that each specification revision is a move toward a meaningful performance quality and not a perpetuation of the present situation.

The era has passed when any residual component from crude oil could be considered a potential paving asphalt. Quality products require the use of selected crudes and/or special processing methods. Present trends toward improved specifications are serving to make this fact more apparent all the time.

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About the Author

Vaughn Smith is vice president of American Bitumuls & Asphalt Company in charge of research, product development and technical service. Smith received a B.S. degree in chemistry from the University of California in 1939 and immediately joined California Research Corporation. He has been active in asphalt research dealing with improved asphalts and development of improved highway pavement design and construction procedure. He has served as technical assistant to the manager of petroleum products research and development for California Research Corp. concern with development and improvement of lubricating oils, engine fuels, greases, industrial lubricants, in addition to burner fuels, asphalts, and special products. In 1958 he became vice president of American Bitumuls & Asphalt Company. He is a member of the American Chemical Society and a registered engineer in the State of California.

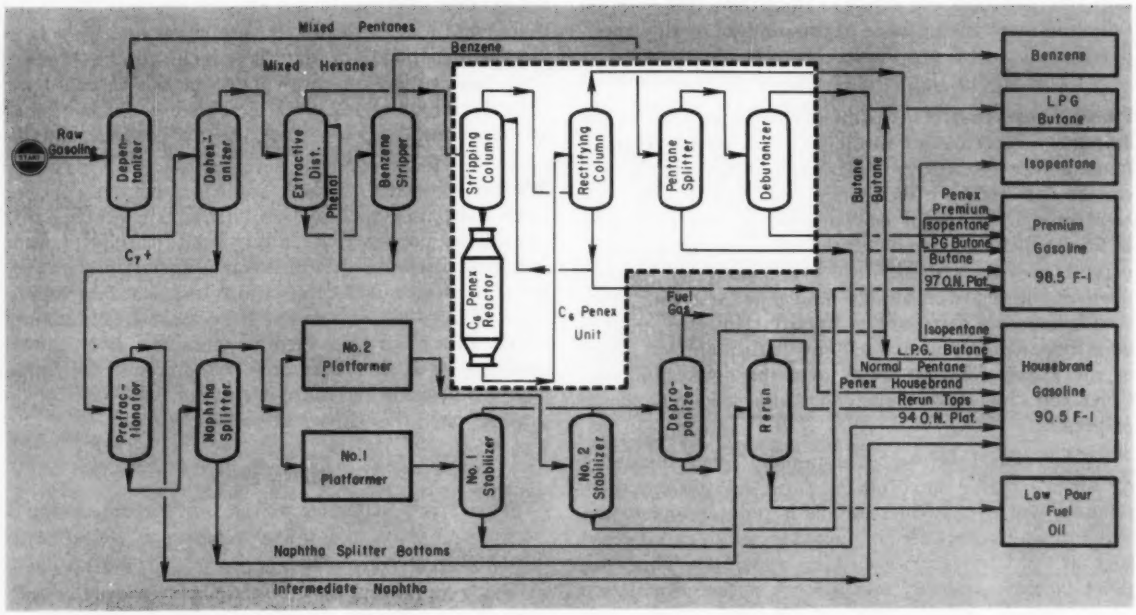

FIGURE 1—Here is how the C_6 isomerization unit and pentane splitter fit into the refinery scheme.

How C_6 Isomerization Works for Atlas

Over a year's commercial operation of a Penex C_6 isomerization unit proves successful for Atlas Processing Company. The data given here will show what you can expect to pay for the benefits of Penex

Vernon B. Chance, Atlas Processing Company
Shreveport, La.

Nellson R. Adams and Frederick G. McWilliams
Universal Oil Products Company
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IN SUCCESSFUL OPERATION since mid-July 1958, a Penex C_6 isomerization unit helps Atlas Processing Company produce its present high quality gasoline. The Penex process along with a pentane splitting system gives a much higher anti-knock quality to both premium and housebrand gasolines without appreciably increasing either gasoline volatility or vapor pressure.

Although this article presents one logical solution to the octane problem in the domestic refining picture, it has much broader ramifications. For example, many refineries in Europe, Africa and Asia are confronted with the same basic problem; namely, that of producing their entire requirement of high octane motor fuel from a straight run gasoline with a 325° F end point; whereas the Atlas charge stock is a full boiling range material with a 400° F end point. The Penex paraffin isomerization process offers great promise in this direction. Another development, announced early in 1959, the Molex[1] normal paraffin separation process, offers still further commercial possibilities in the production of highly isoparaffinic fuels.

A VIEW OF THE OCTANE SITUATION

Atlas recognized the basic need for octane improvement at the Shreveport, Louisiana refinery many years ago. It was realized that the Atlas plant would have

little justification to consider the octane improvement processes such as catalytic cracking since an appropriate charge stock was not available in a refinery designed to process distillates. Accordingly, the initial octane improvement technique applied by Atlas in 1952 was a UOP Platforming unit. As the octane requirements rose and Atlas ran larger quantities of distillates, a second Platforming unit became necessary. This second unit was installed in 1955.

During the early stages of the Atlas development, benzene became an important product so a phenol extractive distillation unit was installed with its associated feed preparation facilities. This unit took advantage of the extraordinarily high benzene content occurring naturally in the hexane fraction.

Atlas continued to process larger quantities of distillates and the required octanes demanded higher Platformer severities. To meet the immediate demands, a prefractionator was installed so that more select cuts could be processed in the Platforming units. The final premium and regular gasolines were made by selective blending of various refinery cuts.

A dehydrogenation-alkylation scheme utilizing butane as a feed stock was examined at one time as a way to provide a high octane blending component. The product was expected also to offset the increase in volatility and sensitivity generally associated with higher severity reforming. It appeared this route would prove attractive since butanes were sold at this time for distress prices of 2 to 2½ cents per gallon. A dehydrogenation-alkylation study was made, but by the time it was completed butanes were selling for 5½ cents per gallon. Unfortunately, the study showed that, at that time, the process would be uneconomical when butanes were priced above 4 cents per gallon.

Isomerization of pentanes and hexanes was the next scheme examined. At that time, no attractive commercially demonstrated process was available. However, a short time later Universal Oil Products Company announced the availability of the Penex process. Not long afterwards Atlas decided to build a C_6 Penex unit because such an installation appeared to be best suited to their requirements.[2] Simultaneously, Atlas installed fractionation equipment to provide isopentane, primarily for blending into premium gasoline. The basic problem was to increase the anti-knock quality of both premium and housebrand gasolines without increasing either gasoline volatility or vapor pressure. Penex C_6 isomerization fitted in ideally under these circumstances.

PENEX GIVES AN ANSWER

The investment requirement for the Penex unit was approximately $1,400,000. The way the C_6 Penex unit and a pentane splitter fits into the present refinery scheme is shown in the flow diagram of Figure 1.

About the Authors

Vernon B. Chance is president and director of Atlas Processing Company, Shreveport, La. In 1924, Chance joined the Shreveport El Dorado Producing and Refining Corporation, one of the previous owners of the facilities now owned by Atlas Processing Company. Having handled various operating jobs, he was elected vice president and manager in charge of refining in 1943, and president and director in 1945. In 1950, the refining and pipe line facilities were purchased by Atlas Processing Company. At that time, Chance was elected vice president and director, and elevated to president and director in 1952.

Nellson R. Adams is a member of the Commercial Development Department of Universal Oil Products Company, Des Plaines, Ill., where he assists refiners from various parts of the world to find optimum use of refining processes. Before joining Universal, Adams was manager of the Refinery Plans Division of The M. W. Kellogg Company. A graduate of The Pennsylvania State University, and a licensed professional engineer, he is a member of the American Chemical Society, the American Institute of Chemical Engineers, and The American Petroleum Institute.

Frederick G. McWilliams is a process engineer in the Commercial Development Department of Universal Oil Products Company, Des Plaines, Ill. As a technical sales representative, he specializes in the economic analysis and engineering coordination of refinery process equipment. Holding a B.S. degree in chemical engineering from Northwestern University, McWilliams joined Universal in 1956.

Before the installation of these new units, the mixed hexanes were blended into the housebrand gasoline and the mixed pentanes were blended into both premium and housebrand grades. Furthermore, the bottoms from the two Platformer stabilizers were not segregated, but were blended in both grades of gasoline.

A comparison of the production and quality of gasoline produced before and after the installation of the Penex unit and a pentane splitter is shown in Table 1.

The greatly improved research octane picture is im-

TABLE 1—Penex and Pentane Splitting Increases Octane Levels

Grade	BEFORE			AFTER		
	bpcd	Vol. %	Research Octane	bpcd	Vol. %	Research Octane
Housebrand	11,580	75	89.5 @ 2.8 ml TEL	9,689	65	90.5 @ 2.85 ml TEL
Premium	3,750	25	94.5 @ 2.98 ml TEL	5,225	35	98.5 @ 2.75 ml TEL
Total	15,330	100	.....	14,914	100	.....

How C_6 Isomerization Works for Atlas...

mediately apparent. The yield loss is only slight and compensated for by an increased butane production of 190 bcd. Of even greater significance is the vastly improved road octane ratings of the gasolines due to the inclusion of high concentrations of iso-paraffins in the final blends.

Details of the C_6 Penex feed stock and of product inspections have been reported by Belden and Adams[3] and are reproduced here as Tables 2 and 3. Typical inspections of the hexane feed stock together with comparable inspections of the premium and housebrand blending components produced in a 35/65 volumetric ratio, basis fresh feed charge stock are shown in Table 2. Typical calculated road octane ratings of the blending components which are significantly higher than the F-1 (Research) ratings are shown in Table 3.

The total direct operating cost for running the essentially self-contained new facilities at Atlas, including all utility costs, comes to $1,751 per calendar day. This provides for the complete operation of the 3,750 bcd C_6 Penex section plus the 4,900 bcd pentane splitter and debutanizer which follows it to provide a butane blending stream or butane LPG.

The total operating cost mentioned may be broken down into the two major cost components presented in Table 4.

These direct operating costs do not include the value of the Penex off-gas used as fuel. This is estimated to be worth $157/cd, mostly chargeable against the Penex unit.

Thus it is apparent that the C_6 Penex operation at Atlas has a total direct operating cost of approximately ¾ cents per gallon of total Penex product. This is not a high cost when considering the excellent yield and the high quality of the C_6 products. The pentane splitter column together with its debutanizer has a typical operating cost of about 15 cents per barrel of fresh charge.

In summing up the over-all aspects of the Atlas C_6 Penex and pentane splitter installation, it is believed that the careful planning and successful completion of this installation is a significant factor in giving Atlas the favorable gasoline marketing position it now holds.

TABLE 2—Atlas C_6 Penex Unit—Product Quality

	Fresh Feed	Premium Component	Housebrand Component
API Gravity	79.6	83.2	79.6
ASTM Distill, °F			
IBP	143	128	143
50%	147	133	147
EP	156	138	158
RVP psi	6.1	8.1	6.5
Octane Ratings			
Research Clear	60.6	83.9	70.2
Research + 3 ml TEL/Gal.	84.2	98.4	90.1
Motor Clear	60.2	83.8	69.8
Motor + 3 ml TEL/Gal.	85.2	103.2	90.3
Composition, Weight Percent			
C_4	.....	trace	.....
Isopentane	.....	0.7	.....
n-Pentane	0.4	1.3	0.1
Cyclopentane	0.7	1.3	0.3
2, 2-Dimethylbutane	2.9	30.9	2.3
2, 3-Dimethylbutane	5.0	14.0	7.3
2-Methylpentane	28.9	43.2	41.1
3-Methylpentane	16.0	8.1	23.5
n-Hexane	37.2	0.5	16.2
Methylcyclopentane	6.1	.....	7.6
Cyclohexane	1.6	.....	1.1
C_7+	1.2	.....	0.5

TABLE 3—Calculated Road Octane Rating of Penex Products

Component (+ 3 ml TEL/Gal.)	Research	Modified Unlontown	High-Speed Modified Borderline
Premium	98.4	102.4	104.4
Housebrand	90.1	93.6	94.2

TABLE 4—Cost of Penex and Pentane Splitter

	$/Calendar Day	
	3,750 BPCD C_6 Penex Unit	4,900 BPCD Pentane Splitter & Debutanizer
Total Operating Labor	350	162
Maintenance (Labor & Matl.)	280	135
Steam		
51,000 lb/hr (250 lb. at fuel cost)	130	116
53,000 lb/hr (15 lb. at 15¢/M lb)	.....	191
Water (make-up only)	8	12
Power at 1¢/KWH	10	8
Misc. chemicals Catalyst cost Royalty	170	10
Taxes and Insurance (estimated)	110	59
Total Operating Cost as above	$1,058	$693
Operating cost per bbl. Fresh Feed	28.2¢	14.15¢

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"How Much Future Octanes Will Cost," Vol. 36, No. 5, pp 209-212 (May 1957).

"Case For Upgrading Natural Gasoline," Vol. 36, No. 7, pp 187-189 (July 1957).

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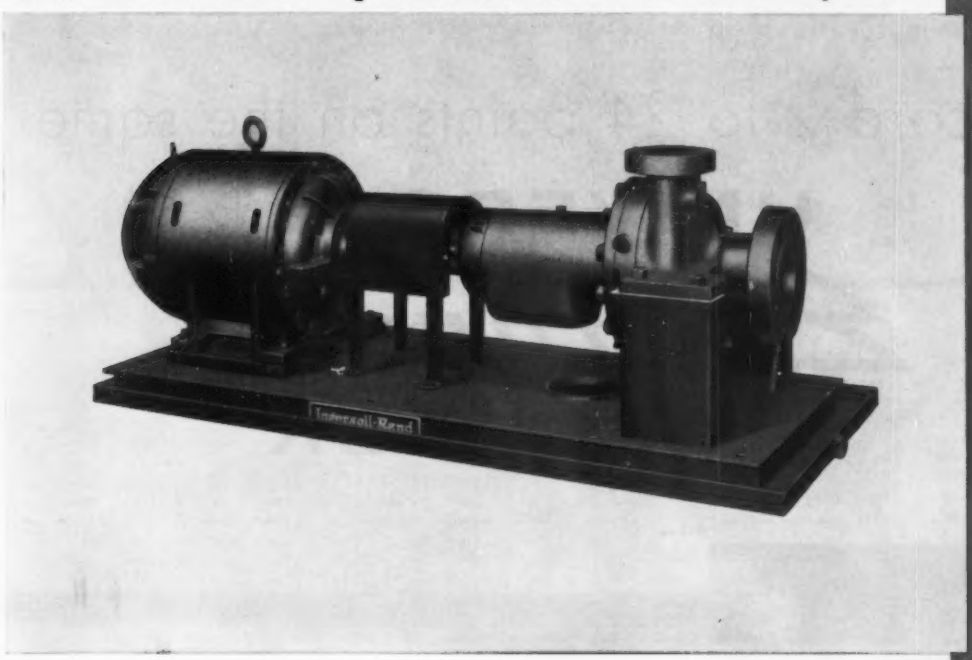

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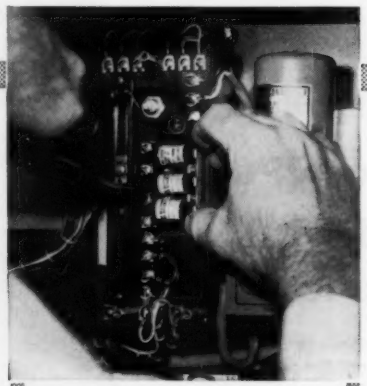

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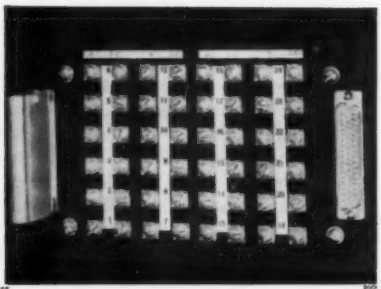

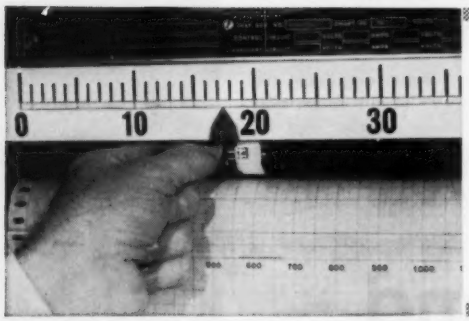

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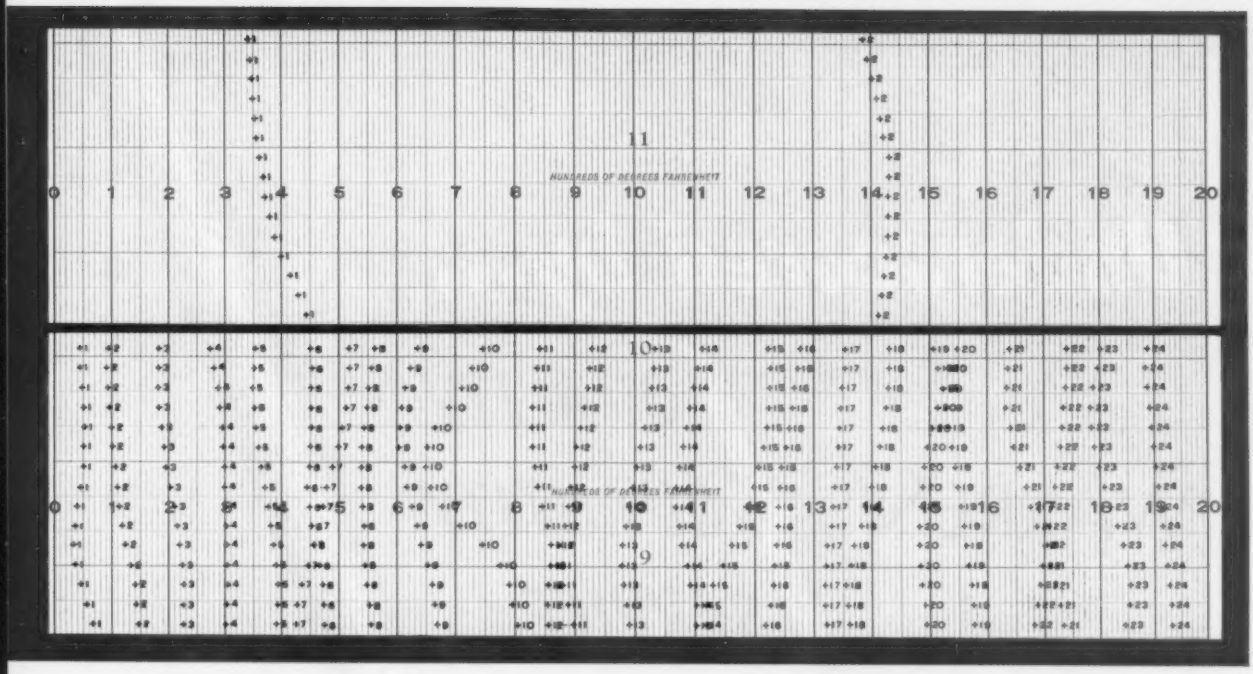

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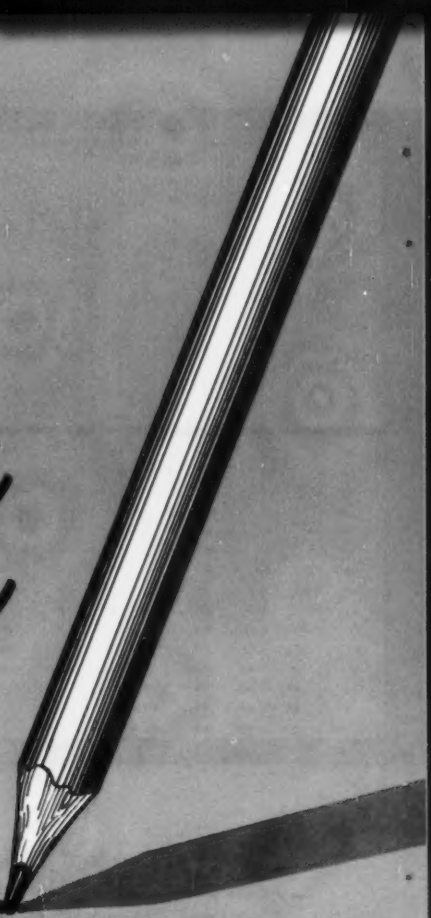

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So You Want to Be a Success . . .

Before you make any more plans for the future, be sure to read this bird's-eye view of the Executive, the Supervisor and the Engineer—and how each fits into the industrial way of life

Dave Tver
Petty Geophysical Engineering Co., San Antonio, Texas

EVERY PHASE of business today is being subjected to microscopic study to determine what will be required in the way of managing ability, materials, machinery and energy to insure greater productivity.

No stone is being left unturned to develop everything (including man) into a precise formula. The worker is being physiologically and psychologically dissected. We are trying to find the ultimate in intelligence, stamina and emotional strain.

The managerial level has received particular attention. Everything possible is being done to develop a set of characteristics for each type of management position, from the extrovert sales manager to the introvert controller. Drawing up lists of "essential qualities" for executives has become the standard pastime of company management development experts and management consultants.

From their various studies and observations we have learned that all that is needed to become an executive is emotional stability, drive, dependability, common sense, integrity, curiosity, courage, loyalty, technical knowledge, interest in people, intelligence, imagination, the ability to perceive, depth of interest and a strong stomach.

The worker is also no exception. He must undergo a thorough physical examination to determine his physical fitness for the job. If he uses his hands, the upper extremities receive particular attention. If he stands or walks, the lower extremities are scrutinized. The physical examination becomes the basis of establishing a human depreciation schedule.

Upon passing the physical examination he then is subjected to a series of psychological examinations to determine his interests, aptitudes, intelligence, dexterities, personality and fitness to become a leader. He is no longer subject to the simple industrial tests, but now must wade through a maze of clinical tests from the Rorschach to the Thematic Apperception Test. If he passes he feels superior to the masses; if he fails he develops a complex.

THE EXECUTIVE

If an examination reveals a man to have leadership capabilities, provisions are made on a promotion chart (whether he desires it or not) denoting same, and his course of destiny is set by paralleled and vertical lines and boxes. He may start off with his name in a circle at the bottom of the chart, with the next step in the triangular area. The speed of his ascent will be determined by the color of his circle, tri-

"From various studies and observations, we have learned that all that is needed to become an executive is emotional stability, drive, dependability, common sense, integrity, curiosity, courage, loyalty, technical knowledge, interest in people, intelligence, imagination, the ability to perceive, depth of interest and a strong stomach.

"The worker also is no exception as he must wade through a maze of clinical tests. If he passes he feels superior to the masses; if he fails he develops a complex."

"The engineer is an individual unto himself. In the industrial society he is the 'blue blood' and the 'blue book.' From his fountainhead pours forth the ideas of tomorrow."

angle, or box. If he is particularly gifted he will run through only half of the spectrum. If not, he must patiently change colors from "not ready" to "now" on each level. He will soon discover green is the "open sesame" of all organization charts.

If he is an engineer, and becomes a good one, then it is inevitable that he assume the responsibility of managing other engineers. Thus instead of a good engineer, he must now become a good manager of men and policy. The tools of a trade he is unfamiliar with he must now learn.

A committee is appointed to review his background and determine what he will need in the way of additional training to qualify for running a department or division. A "halo" is now set above his box in the organization chart. For an indefinite period he will remain in suspended animation while he attends schools specializing in management, human relations, finance, sales, law and accounting.

The Halls of Ivy. Here in the heady atmosphere of the ivy covered campuses he will listen to lectures, participate in workshops, caucuses, smokers, role playing sessions, business decision games, and every other group technique designed to cram a lifetime of experience in two weeks.

He is now being polished as the heir apparent and will appear in a little box under the big box of the individual at the top of the chart.

Once he assumes the responsibility of a manager he finds himself at the point of no return. He is now a slave to the chart that will shape his destiny. He is trained to become the perfect manager, a leader of men, and is given responsibility commensurate with his abilities. He is also given hours commensurate with his responsibilities—sunup to sunset.

Varied Incentives. In exchange for his full and undivided attention to business, his reward will be monetary. Stock options, insurance, thrift plans and many other varied incentives to insure his unflagging interest—even though in many instances taxes may make them more symbols than spending realities. However, these incentives have proven potent catalysts in developing successful executives.

With the executive class there also goes the status symbol. From the parking lot to the executive washroom and lunchroom, the special privileges denote corporate rank. In many concerns the corporate caste system has become formalized and rigidfied. One company divides its management into five levels for the purpose of distributing special privileges. When it comes to company cars, Class 1, division managers and higher, can choose between Cadillac and Imperials. In Class 5, the sales representatives level, the employe can feel free to choose from any of the low priced models of Chevrolet, Ford and Plymouth.

Even in the office, status is important. The size of the desk, the quality of the drapes and capets in private offices, the number of windows and the overall nature of office furnishings are a factor. These symbols also serve to underscore the lines of authority and remind employes where the power actually resides.

No Time. To the executive, the family has now become a secondary to success. He may see them frequently, but mentally he is not there. He may raise a family which he really will never get to know. Relaxation is taken between trips, meetings or while entertaining a client at a convention. The country club and the golf course have become a business deduction.

He buys a larger home, which he seldom lives in, a pool he seldom will get a chance to swim in. He saves money for his retirement which he is doubtful he will ever make.

He states he would like to relax but now he has a responsibility bigger than he. He has risen to the higher echelon of management, the ivory tower; he has been told and believes he has an important responsibility—first and foremost to the stockholders, then his customers and finally the employes. He cannot betray their trust.

He has stockholders who demand dividends and growth, employes whose jobs must be assured, and customers who must be satisfied and retained. He now believes in his own mind that the company depends solely on him. He is now the guiding force; destiny has chosen him to develop the business so that it will become his living memorial. He has now taken all the vows except that of priesthood.

Higher and Higher. Without realizing he has developed an unconscious compulsion to climb ever upward, to constantly do bigger and better things. He can no longer stop as he has become a creature of habit. Retirement or slowing down as such would mean slow death.

When he finally arrives at the top, he will at last achieve the ultimate —an oil painting of himself in the board of directors room.

THE SUPERVISOR

The man in whom the worker relies for leadership and security is his foreman or supervisor, a man with plenty of problems of his own in relation to his changing role in the plant.

Most progressive managements now have elaborate management policy guides, emblazoned with gold letters to accentuate the authority of what is contained within. The policy statements set forth, some in great detail, some in no detail at all, just what management thinks and expects to be done in any given situation. It is here the expression originated, "There is no reason, it's just company policy."

Unfortunately, the supervisor has had little or nothing to do with formulating these policies. When it is necessary to change or augment them, written instructions descend from some hallowed place above. If he should question their wisdom he is told, "this is management policy,"

yet he is told he is a part of management.

As the unions have grown, the supervisor has lost more and more of his power and status to the union steward and business agent. The grievance procedure often goes around him or above him, to persons in higher authority.

Often the supervisor sees himself only as a buffer, battered by the worker on one side and management on the other. Before he can act he must consider company policy, the effect on the union, advice from personnel and other staff consultants and the needs of the other departments. It is small wonder that the supervisor is sometimes uncertain how much real authority he has.

Man of Many Roles. And now, in addition to technical leadership, problems of morale and psychological motivation are thrust upon him. Sometimes he sees himself as a combination nursemaid, father confessor and amateur psychologist. He is prepared for little of this by training or experience. Yet, he cannot fall back on old-fashioned aggressive and punitive techniques of supervision. Progressive management now recognizes that profitable production has to be wooed, not wrung from workers.

Management has felt because of this, supervisors must be trained. As a result, supervisory training programs have sprung up all over the country. Long courses, short courses, technical, administrative, leadership quality training, and psychological understanding of human behavior. Everything from how to deal with problem employes to how to get along with the union steward. Some are sound, others just a superficial lick and a promise.

The properly trained supervisor, it is hoped will give his men adequate leadership, personal recognition, counsel, direction and paternal benevolence. This in turn, is expected to cut down on absenteeism, intra-plant fueds and factions and the stresses and strains of the job.

THE ENGINEER

The engineer is an individual unto himself. In the industrial society he is the "blue blood" and the "blue book." From this fountainhead pours forth the ideas of tomorrow. He looks at disdain at anything or anyone not connected directly with engineering or manufacturing. He is perpetually trying to find out who is more important the staff or the line—and for that matter the meaning of line and staff. He is alpha and omega.

He feels that the sales department should be able to sell anything he can manufacture or develop. He feels that cost accounting and budgets are necessary evils that must be tolerated. He and the accounting department have only one thing in common, they work for the same company.

To this end, two definitions were developed by an unknown author describing the accountant and engineer's opinion of each other.

AN ENGINEER AS SEEN BY THE ACCOUNTANT

"The typical engineer is a large full-blooded enthusiast, a cigar smoker, with hair on his chest and a YMCA secretary's smile. He talks in astronomical figures, and abhors detail. His limits of accuracy are plus and minus $5,000, and he brags that he stays within those limits. He is the dispair of auditors, only exceeded in this respect by personnel people. Happily he is a mule, without pride of ancestry or hope of posterity, and goes to an early grave, cheerily waving his slip-stick mourned by none and remembered only by his creditors."

AN ACCOUNTANT AS SEEN BY AN ENGINEER

"The typical accountant is a man past middle-age, spare, wrinkled, intelligent, cold, passive, non-commital, with eyes like a cod fish, polite in contact, but at the same time unresponsive, calm, and as damnably composed as a concrete post or a plaster of paris cast. He is a human petrification with a heart of seldstar and without charm, passion, or sense of humor. Happily, they never reproduce and all of them finally go to hell."

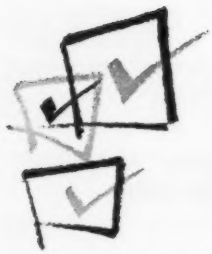
A Real Goer. An engineer will seek to further impress his importance upon the world by wearing several engineering and fraternity keys and pins and by emblazoning his office walls with diplomas and society awards. He joins at least five engineering societies that are highly restrictive in membership—only engineers, petroleum, mechanical, electrical, geological, industrial, and sanitary.

He attends meetings and conventions to exchange papers, ideas and jokes and argue about what the world is going to look like in the future, after he and others of his specie improve it or make it over. It appears to his boss that he is always coming from or getting ready to go to a technical meeting or convention.

In spite of all this, he is human as those above him and below him. He has his gripes which go unanswered, but are there. A survey by the Professional Engineers Conference Board revealed that 45 percent of the engineers in industry are not satisfied with the size of their pay checks; 34 percent of them did not feel that their prospects for advancement were good; 55 percent did not know whether their employer was satisfied with their work and 38 percent felt their companies were not making effective use of their training. In short, has has much of the same complaints as his fellow industrial workers, and must be, therefore, just as human. ##

About the Author

David F. Tver is executive vice president for Petty Geophysical Co., San Antonio, Texas. He holds a B.S. and an M.S. degree in clinical and industrial psychology and has supplemented his training with courses in industrial engineering. During World War II he served as a clinical psychologist and personnel consultant with the Medical Corps. He then joined Anderson Prichard Oil Corp., where he was made director of industrial relations. He joined Petty Geophysical in 1958.



Test Yourself on Labor Relations

No. 1. Engineers Do Routine Shift Work?

The company had agreed to a policy which read, in part "supervisors, foremen and others outside of the bargaining unit shall not perform work normally performed by employes in the bargaining unit except for purpose of instruction and tryout of tools and equipment, or in cases of extreme emergencies necessary to the proper function of the plant."

When an important customer called and said he was returning a defective shipment, management promised to repair the units immediately. A crew of workers was quickly assigned to put the products in good order. The supervisor figured that the job would be finished by the end of the shift and didn't assign any employes to overtime. He was called to a management meeting. When he returned he found that the men, having completed their shift, had already left—and the job was still not finished. He immediately got hold of a group of junior engineers. With their help, he completed the repair of the units, packed and shipped them back to the customer.

The next day the employes filed for overtime pay because they claimed that they should have been assigned to that overtime work. The company refused and argued:

1. We had an extreme emergency on our hands and had a right to assign the completion of this job outside the bargaining unit.
2. We made a mistake in estimating the time for the job incorrectly. But we had to act immediately.

The employes were not impressed. They said:

1. This was not an "extreme emergency." If it was, the supervisor wouldn't have left to go to a meeting.
2. We could have been called back to do the job.
3. If management miscalculated time for the job, we shouldn't be made to suffer a pay loss.

Test Yourself:

Were the employes: RIGHT ☐ WRONG ☐

No. 2. Wildcat Strikes

The company and the union were having a "hassle" over whether or not management had a right to use outside contracts to install some new equipment. The company said "yes" and the union said "no." The plant superintendent suggested a solution—"Let's arbitrate and get a quick decision."

The union refused. Instead it ordered the workers out two days before a holiday. The company got in touch with the international branch of the union. The parent union agreed that this was a "wildcat" strike and persuaded the men to return to work.

The company disciplined the workers by denying them pay for the holiday which came while they were striking. The union protested. It claimed:

1. The contract calls for holiday pay and you cannot use this as a disciplinary measure.
2. The agreement does not list "strikes" as a reason for denying holiday pay.
3. If you want to discipline employes for "'wildcatting" you can do so some other way but you can't deny them benefits like holiday or vacation pay.

The company maintained that it had a right to select any discipline it chose.

Test Yourself:

Was the company: RIGHT ☐ WRONG ☐

Case No. 3. Absent 39 Times One Year

John Meeker, a 7-year employe of average efficiency, began to accumulate a series of absences last year. It seems he was having a lot of family problems. His wife was sick and he had six children, three of whom were not in good health. After 10 absences he received a written warning notice. After 38 absences he was given a second notice. The next time he was absent, he was fired. The company had a written rule that any employe who was chronically absent would be warned, and after 2 such warnings would be subject to discharge. John protested:

1. I had a lot of troubles and couldn't come to work regularly.
2. I'd like another chance.

The company was impatient with John's argument:

1. We put up with 39 absences. That's enough.
2. We go by the rules—2 warnings and out. That's fair to everybody.

Test Yourself:

Was the company: RIGHT ☐ WRONG ☐

Answers on Page 332

ORGANIZING A MANAGEMENT DEVELOPMENT LAB

Ordinary education or work situations rarely provide a person the opportunity to test his social skills. But here is a method which enables you to measure how your behavior is seen by others, and whether or not you understand what makes a group "go"

Robert R. Blake and Jane S. Mouton
The University of Texas, Austin

THERE ARE THREE KEYS to understanding the management or applied group dynamics laboratory approach to training for more effective decision-making. These are:

1. The laboratory as the human side of an actual refinery
2. The strategy for acquiring knowledge
3. The feedback for reflecting behavior

Now, let us discuss each of these in some detail.

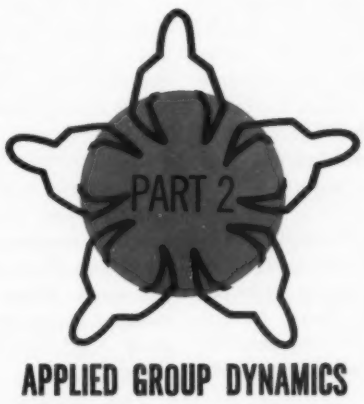
KEY 1—THE HUMAN SIDE

The first key is that a laboratory is a replica of the human side of an actual refinery. Therefore, participants have different ranks. Department heads are there and shift foremen are there too. Technical and practical people mix with one another. All try to work together.

Those of lesser rank or without technical training feel the same pressures and concerns for being understood, accepted, and appreciated that they would under actual refinery operations. They may try to express themselves openly and aboveboard so that those of higher rank or with college technical training will know what makes them tick, what frustrates them, and what they really have to offer beyond their present opportunities to participate in management decisions. They experience much difficulty in being heard, in getting through.

People of higher rank, on the other hand, feel obligated to lead and direct. They take over responsibility, particularly when the laboratory action is bogged down and things are not going well in much the same way as under typical refinery conditions. However, they, too, find difficulty in making sense and in getting others to follow. The compounded blindness of practical people wanting technical people to take over plus the need of technical people to do so leads rapidly to a concentration of power in the hands of the highest ranking people.

Only when they forget prerogatives, privileges, prestige and, in a sense, the false status accorded them by the awe in which the practical people hold them, and "join up" to get the job done, do the high ranking people become truly active, contributing, effective participants.



Only when a practical man forgets he isn't educated and acts as intelligent people do, exerting legitimate influence, does he find that it usually is ability not rank or education, that results in some person's being given leadership and in others falling in line with him to make it work. When that happens, problems of participation, communication, and decision-making related to status somehow disappear. When decisions are turned out they have a superior quality to which all can subscribe.

Human Problems. When participants try to work together under laboratory conditions, many of the central human problems in a refinery are reproduced in action much like a war game simulates a military battle.

Included are all of the problems involved in becoming a group such as conducting a meeting when the agenda includes what ought to be talked about, not just what it's comfortable to discuss; understanding the deviant,

what makes him tick, and what he has to offer if he isn't snuffed out; and seeking for consensus rather than settling an important issue with a brittle majority. Learning how to work with others in setting clear, realistic goals, then cycling back to determine how well actual performance is leading toward their attainment is also included.

Unlike war games, however, there is no spirit of a game in the applied group dynamics or management development laboratory. People play for keeps in the sense of making decisions that are deeply meaningful to them. They learn a lot about themselves and about others that they didn't know before. They get insights they can take back and apply in the home situation. It's also unlike business games because it focuses on problems involving the effective use of human resources. Strategies and tactics of the economic or engineering aspects of decisions are not even considered.

With these economic and technological considerations eliminated, participants can see how they disregard, misuse, mistrust, and even violate one another. Managers are unable to hide behind the blinding influence of cost records, market conditions, inventory figures, or production runs. Feelings, thoughts, and approaches to cooperation between people stand out in bold relief.

Now, you may be wondering why we should be concerned with training people for the more effective use of human resources in the industrial setting? What is the rationale of training? In this question is contained the second key.

KEY 2—ACQUIRING KNOWLEDGE

The laboratory method of experimenting with human factors can be understood by drawing an analogy with the strategy of a physical scientist. What does a physical scientist do to test a new idea? First, he states it in as clear a way as he can. Then he tries it out for size. He sees if it works in an experimental situation. He tests it and retests it and experiments until the idea is perfected. Then he changes the conditions to see if it still works. When he's satisfied he knows and can state the principle involved, he starts the cycle over again. When he finally gets it perfected, he publishes the results. The ideas of many scientists are in every university library in the country. They are there to be used by anyone who is able to make practical applications of them.

The social scientist employs the same strategy. When his ideas are perfected, they are also available in libraries for anyone who is able to find practical applications for them. But stop! The analogy ends right there. At this point a radical difference occurs between the application of physical science and the application of social science knowledge.

Role of the Manager. Refineries make use of physical ideas by employing a specialist to tell them "how to do it." Then engineers perfect the operations needed to turn out a finished product. But a refinery can't do that with social science knowledge. The reason is simple: a manager can't bring in a social science specialist to tell him how to manage! If he does he abdicates to the scientist his managerial responsibility. The approach is no good in spite of the fact that managers occasionally take the consultant's bait. It won't work over the long haul. Every manager must find out for himself how to use this knowledge within his own intellectual limitations and basic social skills.

How then can he learn social science knowledge? He can't employ a specialist to tell him how to do it and still retain his managerial responsibilities. He can't return to a university to get a Ph.D. He's got to become an applied human scientist *himself,* and he's got to do it in a highly concentrated training program.

Thus, the second key to understanding a management development laboratory, then, is that the manager learns to experiment, to invent, to devise, to test ideas and methods. He sees how they work on himself before he employs them as a basis for cooperating with others. But how can a manager become at the same time a teacher and a learner? On the job as an apprentice? No, it wouldn't work. The risks are too great, just as the risks are too great for a physical scientist to experiment with his ideas on the production line. By taking a course in management at one of the leading universities? No. That approach is too time-consuming, too expensive, and usaully too abstract to hit the mark. Only in the setting of a management development laboratory can the ideas of social science be explored, evaluated, tested and perfected by a manager for on-the-job application. The description we will present later is of an industrial laboratory, though many of the ideas and methods used have been perfected in non-company laboratories.

Key 3—FEEDBACK

The third key is based on feedback. Feedback in a management development laboratory means trying some behavior and getting back signals on how others react to it. Feedback is a social mirror—it tells how others react to your behavior. The distinctive feature about training feedback is that people tell one another what they would ordinarily avoid saying.

Let's take an example. In place of bottling up his unexpressed feelings, a low ranking member of a group gains the freedom to tell a high ranking person that his questions are punishing, destructive and belittling. The high ranking person does not see the impact of his questioning this way, but feels his questioning is aiding the person of lower rank to express himself.

When the two come together, with the low ranking person saying that certain kinds of questions hurt, and the high ranking person saying he's trying to help, both learn something about human reactions. The low ranking person learns he's not being attacked, and the high ranking person realizes he's got to be more sharing and open if he wants to trigger free and spontaneous participation.

This continuous checking and rechecking process permits a person to measure how his own behavior is seen by others, whether or not he can accurately assess the behavior and motivation of another person, whether his judgments of human events fit what others see, and whether or not he understands what makes a group "go." Through such evaluations it is possible to experiment with and to try different modes of approaching a problem, with the possibility of testing consequences and improving behavior right in the here-and-now.

Ordinary education or work situations rarely provide

a person the open, free opportunity to test his own social skills against training feedback. Training feedback, for example, makes the difference between whether or not a man who says, "I've been with the company 20 years," has had 20 years of experience in learning or 5 years of learning experience four times.

THE TRAINING OPERATION

The objectives described are desirable and realistic for improving relations—for improving the overall batting average of company-wide decision-making. But how can such training be accomplished? The laboratory experiment into group dynamics described here is a highly distilled sifting of ideas and methods from the social science.

Participants and Setting. It is probably best to start a laboratory with 24 persons, though company laboratories have been conducted with 32 or 36. The size is determined by how many people can be away at any one time. Participants are from all ranks of management, from shift foreman to department or division heads or the general manager, and easily could include members from the work force as well. They are from all age groups and all specialties, including technical and practical personnel.

Take them off the job, separate them from the telephone, the harassment of the last decision, or of the next meeting, to a quiet place. Plan to stay for two weeks. Start off, say, on a Sunday afternoon at 2 p.m. A brief introduction includes the gist of what we have said about experimenting with behavior to experience new ways of acting that may not have been tried before. The kick-off calls attention to the ideas and principles of behavior which can serve as blueprints for achieving productive collaboration among individuals.

Laboratory Activities. The two weeks are likely to be as busy and involving as a manager has ever spent. They will include each person's becoming a member of an eight to twelve man development group. Each development group, which is continuously recorded on tape, meets for 40 to 50 hours. In addition to the development group, there are several other learning experiences. One is eight to ten hours of tape listening, where development group members trace the continuity or the breaks in it which influenced the action of the group. Here a person gets a chance to hear himself in the thick of things; either interrupting, cutting people off, ignoring important remarks, or avoiding such things by providing effective alternatives, summarizing, testing a proposal for feasibility and so on.

Another feature is the consultation quartets, where each development group breaks up into four's. Consultation quartets give a man as much feedback as he wants on how his behavior is affecting the group or individual members and how he might change it to get greater impact or to increase his knowhow when it comes to the dynamics of human relationships.

A fourth feature is based on miniature experiments designed to emphasize a systematic point. Problems of decision-making between members of a pair such as a supervisor and a subordinate, within a small face-to-face group, between groups, and within the entire organization are facets of management training open to experimental analysis.

A fifth aspect involves experimenting with and practicing using new ideas for their application in the laboratory and on the job. Here, theories of behavior are examined in detail. The psychology of the individual is one facet involving an examination of differences in time perspectives, goals, ability to organize work in a functional manner and so on.

EXAMPLES OF FEEDBACK

Typical examples of the kinds of behavior that refinery personnel get feedback on are listed below. They define the primary areas of concern felt by people in trying to collaborate effectively with others.

All members of the development group rate themselves and the others in the group on these 27 items. Ratings are in terms of a 9-point scale from "never," through "hardly at all," "seldom," "a few times," "sometimes," "fairly often," "often," "almost always," to "always."

1. Offers constructive evaluation as needed
2. Levels with other members
3. Offers original ideas
4. Expresses self clearly and concisely
5. Summarizes where group stands on an issue
6. Contributes without cutting others off
7. Helps get to the meat of issues
8. Annoys others
9. Yields to group pressures—conforms
10. Sticks to his point arbitrarily
11. Provides helpful feedback to group members
12. Listens with understanding to what others say
13. Takes lead in selecting topics
14. Helps members express their ideas and feelings
15. Shows interest in people and their ideas
16. Encourages group to high level productivity
17. I find it hard to understand what he is trying to say
18. Effectively senses when to talk and when to listen
19. Makes others feel at ease
20. Helps group to stay on target
21. Runs away when faced with a problem
22. Puts group goals above personal needs
23. He fights rather than works
24. He shows that he likes us
25. Blocks the group
26. He likes to wander
27. Dominates and imposes his will on the group

Then in the consultation quartet each person gets the data feedback on how his behavior is seen by everyone else. Thus it becomes the job of each consultation

quartet member to help every other member to interpret, understand and think through solutions for increasing the effectiveness of his behavior. Personal feedback concerning this behavior is given in consultation quartets which are scheduled at various times. Membership in a series of quartets varies with different combinations of people from the same development group for each meeting, but the rule is to compose them so that people of widely different ranks in the organization are together.

Here, then, is an unmatched road to personal learning. The laboratory atmosphere creates an openness and a desire to be helpful which permit people to listen without being defensive. What better contribution to the development of a manager could there be than a situation within which he can gain personal information about himself that his best friends usually withhold?

Here-and-Now Feedback. Here is an example from a development group meeting where members are checking the accuracy of their interpretations with one another.

George to Group

"Earlier in the meeting Joe said, 'I think we need a chairman,' then Andy said, 'Ken, you be the chairman for this meeting,' so Ken became our chairman. I don't think we all agreed to this decision. In fact Frank hasn't participated since."

Andy to George

"We all did agree. I said 'Are there any objections?' and no one said anything, so we all agreed."

Frank to Andy

"But I didn't agree to it. I thought it was a real powerplay."

Andy to Frank

"Why didn't you say so?"

Frank to Andy

"Because I didn't want to be a blocker, and we were having a tough time getting started and I didn't want to upset the applecart."

Oliver to Frank

"I didn't agree either, but everyone looked as if they thought it was a good idea. I didn't want to be an objector."

Ken to Group

"What could we have done at that point to help members speak out, rather than running over them?"

In this example, a member is able to get a fix on how his own behavior is seen by others, whether or not he accurately assesses behavior of another person, whether his judgment of group events is similar to others, and whether his proposals lead to effective decision-making in a group.

In this particular incident, Frank successfully diagnosed a block to effective action. Ken became aware that he fell into a situation which was seen as a powerplay. Andy miscalculated the opinions of all the members when no one responded to his call for objections, and Frank and Oliver learned that they were unable to read each other's protests. George was able to uncork the problem and open the way to test effective means of interacting.

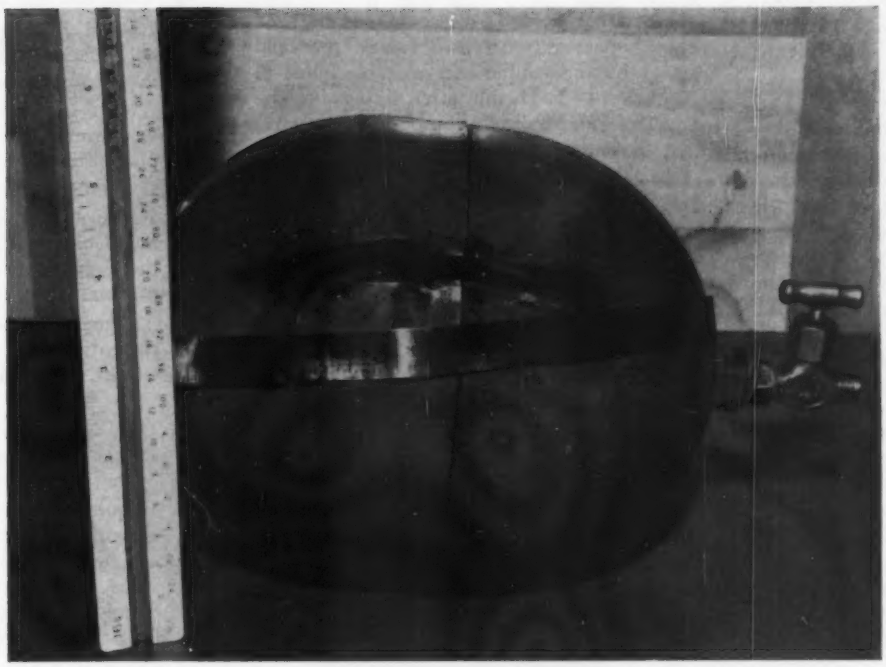
A paradox of our times is that so much group effort takes place among individuals who have had little or no training in the skills of group action. This is particularly so when you stop to consider that much of refinery decision-making is placed in the hands of engineers who, for the most part, have never had academic or other kinds of training in the behavioral sciences.

Thus, in many company situations you hear people say, "What we need to do is to get rid of so many unproductive committees." Perhaps so, but this can also be regarded as desperation, a last resort before giving up. The real goal should be to learn about how committee action can be made effective so as to exploit the tremendous potential for creative thinking that can come from several people sitting down together to tackle a problem. This is particularly true when it is obvious that no one person has "the answer," but that it can be moulded from the blended thinking of several.

All these building blocks of a laboratory that are described in this article are fitted together so that the experience is cumulative over the two weeks. Some kinds of experiences are emphasized early in the program, others later. After such an intensive period a person sees that personal goals and organizational goals can fit together as a basis of cooperation, to replace the authority-obedience system which is causing so much trouble up and down the line.

In Applied Group Dynamics: Part III which will appear next month, the authors discuss such highly interesting and informative points as:

1. **Power as a central factor in human relationship.**
2. **The power spectrum.**
3. **Competition in decision making.**
4. **Powerlessness on the part of supervisors or subordinates.**
5. **Power and personal satisfaction.**



Bomb Ruptured and Flashed. Thermal expansion of the liquid resulting from 49° F temperature rise could have subjected the bomb to 1,000 psig pressure—possibly higher.

Sample Bombs Can Be Bombs!

After reading this case history, you may want to review your own procedures and equipment for sampling light hydrocarbon mixtures

J. C. Ducommun
Standard Oil Company (Indiana)
Chicago

BOMBS FOR SAMPLING light hydrocarbon liquids can be as dangerous as their name implies. This was demonstrated recently at the Mandan, N. D., refinery of Standard Oil Company (Indiana).

A bomb of 1,900 ml. capacity ruptured, releasing butane vapors, which flashed. Fortunately, no one was injured, but the potential was extremely serious. We are reporting this accident because similar accidents may occur in the petroleum, natural gas and chemical industries unless proper precautions are taken.

The bomb involved was an Air Force surplus 1,900 ml. capacity oxygen container, thought to be stainless steel, but later found to be low carbon steel. The design pressure rating was 500 psi, and the working pressure rating was 400 psi.

The bomb was being used as a sample container for field butane. Before delivering the bomb to the alkylation unit, the laboratory had introduced into it about 30 ml. of dry ethylene glycol. An alkylation operator, experienced in sampling field butane, filled the bomb with field butane at a line pressure of 220 psi at a temperature of 26° F, so that water content could be sampled in the laboratory.

Bomb Ruptures. At the refinery laboratory, the bomb was placed in a shaker to thoroughly mix the ethylene

glycol with the butane sample absorbing moisture from the butane. During the shaking, the bomb ruptured (see photo), releasing the contents which vaporized rapidly and flashed at a furnace in which carbon was being burned from a sample of cracking catalyst.

Three persons were in the laboratory when the butane flashed. The fire was extinguished within a minute with carbon dioxide extinguishers thus the damage was minor, confined primarily to a scorched ceiling, broken windows, and bulged fresh air ducts.

The bomb ruptured along longitudinal planes, as you would expect if failure was caused simply by overpressure. No major divergency in the path of the fracture was apparent. Micrometer measurements showed that the wall thickness of the metal shell ranged from 0.031 inch to 0.040 inch. Rupture occurred through the thinnest portions of the hemispherical components, and although there was some local expansion of the metal shell, the expansion did not appear to be attributable primarily to the variation in wall thickness.

Metallographic examination revealed that the bomb had failed in a ductile manner, by the shear mode of fracture. The base material consisted of low carbon steel that appeared to be of normal quality. The two hemispherical components were joined with a copper-base brazing alloy. The brazed joint was sound.

Metal Yield. Calculations based on butane as the contained liquid, indicated that up to the yield point of the low carbon steel, the pressure on the metal shell would increase about 38 psi for each 1° F rise in temperature. We then estimated that the base metal would start to yield at a pressure of about 550 psig. Once the base metal did start to yield, subsequent unit pressure increase per 1° F rise in temperature would have been less than 38 psi.

The bomb had been filled with field butane at a temperature of about 26° F and a line pressure of about 220 psig. Under these conditions, the bomb could have been liquid full with any contained air dissolved in the butane. After being brought into the laboratory and warmed to room temperature of 75° F, the liquid expanded. It appears, therefore, that the thermal expansion of the liquid, resulting from the 49° F temperature rise, could have subjected the bomb to a pressure of at least 1,000 psig, and possibly to even higher pressures if bursting had not occurred.

Overlooked. We concluded that the operator who had taken the field butane sample had probably failed to vent the bomb after filling it. The regular sampling procedure requires venting to assure a vapor space in the container. Although the operator was aware of this and customarily vented similar samples, he admitted that he might have overlooked venting of this particular sample.

Butane samples are vented in the laboratory before being shaken prior to testing. This sample was one of a number which had arrived in a group and it may have been overlooked.

A committee appointed to make a complete study of the subject of sample bombs for high pressure liquid hydrocarbons, is considering, among other things, the following:

1. Standardizing use of 75 and 150 ml. bombs manufactured of monel. Pressure rating of these bombs would be 5,000 psi.
2. Visual inspection of bombs whenever valves are changed, plus pressure testing to 8,000 psi every five years.
3. Requiring specific approval for larger bombs which are to meet these specifications, limiting the maximum size to 300 ml.
4. Tagging each bomb, giving serial number, volume, tare weight, and date for next pressure test.
5. Permitting only trained personnel to take samples of high pressure liquid hydrocarbons.
6. Requiring sufficient outage for all samples taken.
7. Closing the open end of each valve with cap or plug immediately after bomb has been filled and vented to prevent escape of gas if valve fails.
8. Providing carriers for transportation of bombs.
9. Checking all bombs for leaks when brought to laboratory and placing them immediately in a freezer at 20° F. Discarding sample if bomb leaks.
10. Checking outage of each bomb by weighing before distributing for analysis.
11. Keeping bombs in hoods while awaiting analysis or pickup for discard.
12. Providing daily pickup of bombs containing samples which have been analyzed.
13. Discarding sample through a steam vent. Access to the vent shall be in a fume hood.
14. Marking and delivering to the sampling technician for valve removal, all bombs with inoperative valves. This work must be performed in a hood and extreme care used to guard against the possible sudden release of trapped hydrocarbons.

We intend to inform the industry of our conclusions when our studies have been completed. In the meantime, these contemplated precautions may be of value to the industry by stimulating a review of practices and equipment design. # #

About the Author

J. C. Ducommun is general manager of manufacturing for Standard Oil Co. (Indiana). He received a B.A. degree from Moringside College, Sioux City, Iowa, then went to the University of Iowa where he received a B.S., M.S. and professional engineering degrees in civil engineering. In 1927 he was appointed research assistant in the department of hydraulics at the University of Iowa where he served for one year. He joined Standard Oil Co. (Indiana) in 1929 as a design engineer in the engineering department at the Whiting refinery, and in 1932 he organized the Engineering Inspection Department. In 1934 he became assistant general foreman of the Pressure Still Department and three years later was made general foreman of that department. He became assistant superintendent of the Light Oils Division in 1943 and one year later was made assistant general superintendent of the refinery. He was advanced to manager of the Whiting refinery in 1948. In October 1952 Ducommun was promoted to assistant general manager of manufacturing at the company's general offices in Chicago, and four years later was promoted to his present position and elected a director of the company. He is also a director of Calumet Nitrogen Products Co.

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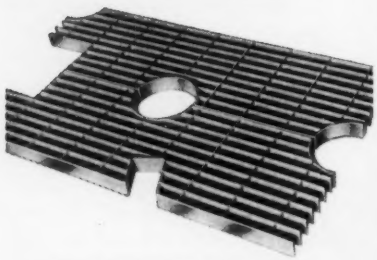

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(Foust, A. S., Wenzel, L. A., Clump, C. W., Maus, L., and Anderson, L. B., *Principles of Unit Operations*, John Wiley & Sons, Inc., 578 pages, $15. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas.)

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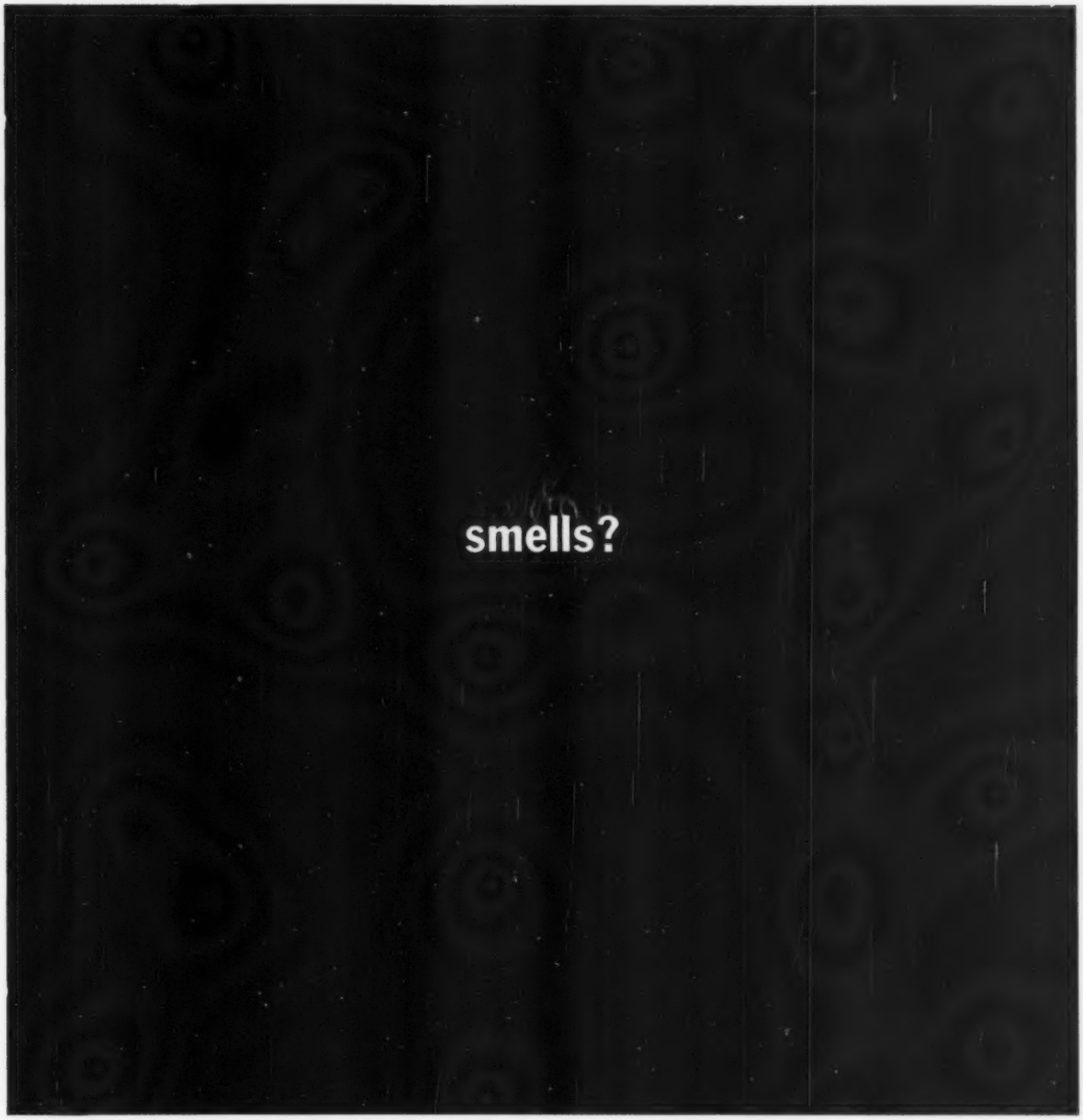

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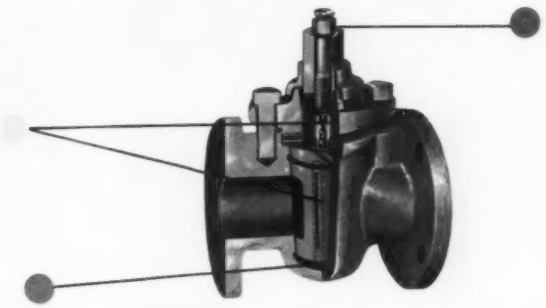

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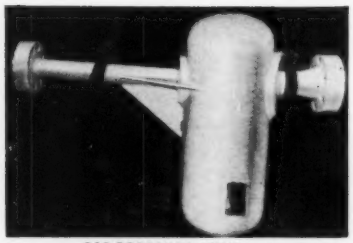

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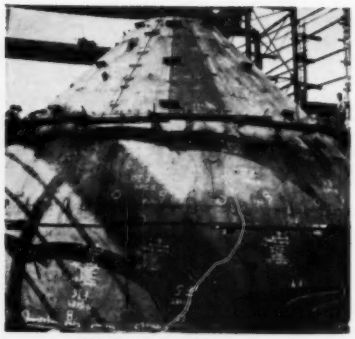

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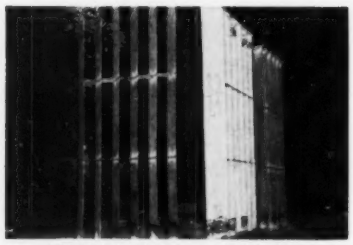

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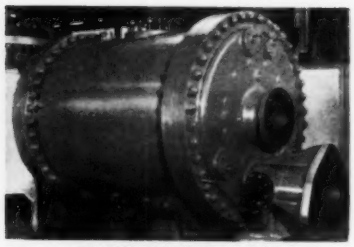
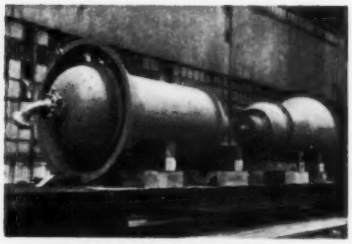
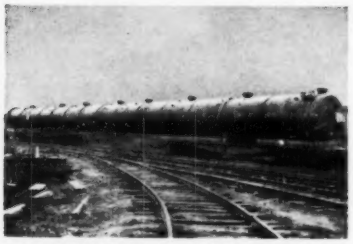


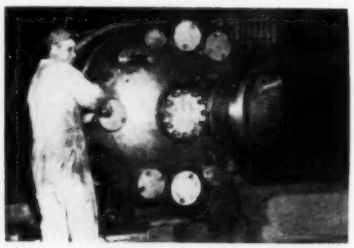
SPECIAL CHEMICAL VESSEL



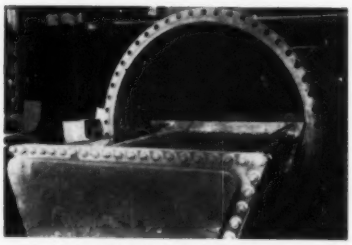
SPECIAL STAINLESS VESSELS



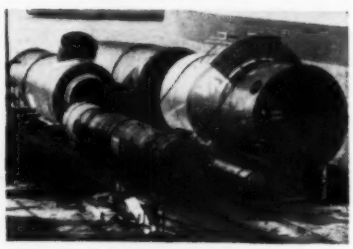
TOWER, 8′6″ dia. x 154′ in length



STAINLESS AUTOCLAVE



SPECIAL CONDENSER



WATER SHIPMENT

MACHINERY PARTS

MADE TO ORDER EQUIPMENT FOR OIL REFINING & CHEMICAL PLANTS

We place at your disposal one of the largest and most thoroughly equipped plants of its kind, featuring advanced production methods with experienced personnel in all departments.

PRODUCTS—Towers, Stills, Condensers—Kilns, Heat Exchangers, Pressure Vessels, Plate Work—All Codes, Any Material, Special Machinery, Machine Work.

SPECIAL SERVICES—X-Ray Equipment—Stress Relieving Furnaces.

SHOPS—Boiler, Welding, Machine, Fabricating, Pipe, Blacksmith, Anglesmith, Sheet Metal, Copper, Separate Stainless Shop.

WATER AND RAIL SHIPMENTS—Our plant, including crane for loading and handling is located on the Delaware River with piers and deepwater to accommodate sea-going ships and railroad connections to all points.

SUN SHIPBUILDING & DRY DOCK COMPANY

CHESTER, PA.

For more data on advertised products, use Readers' Service Cards, last page.

Books . . .

carbon chemistry and the production and uses of derived by-products. There is also a detailed description of the important types of petroleum and a critical comparison of the various methods of refining and distilling.

Among the many subjects covered are production, classification and description of crude oils; composition of petroleum and petroleum products; motor fuels; kerosine; absorbent oils and fuel oils; lubrication and lubricants; and petroleum waxes and asphalts.

(Gruse, W. A., and Stevens, D. R., *Chemical Technology of Petroleum,* McGraw-Hill Book Co., 675 pages, $15. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas.)

Corrosion Data Survey

"Corrosion Data Survey," a new reference work, has been published by Shell Development Co. It has been published in the past with copyrighted editions appearing in 1950 and 1954. The survey represents the latest corrosion information available from scientific literature from all parts of the world. It illustrates in a general manner the behavior of about 1,500 corrosive environments when in contact with approximately 50 constructional materials.

The book is a series of 50,000 charts with about 500,000 reference points that list process streams ranging from abietic acid to zirconium nitrate. It tells at a glance the best type of material to use for a particular stream in concentrations to 100 percent and temperature ranges from 75 to 800°F for corrosion rates of less than 0.002 inch per year to over 0.05 inch per year.

(Nelson, George A., *Corrosion Data Survey,* Shell Development Co., Emeryville Research Center, Emeryville, Calif., $50.)

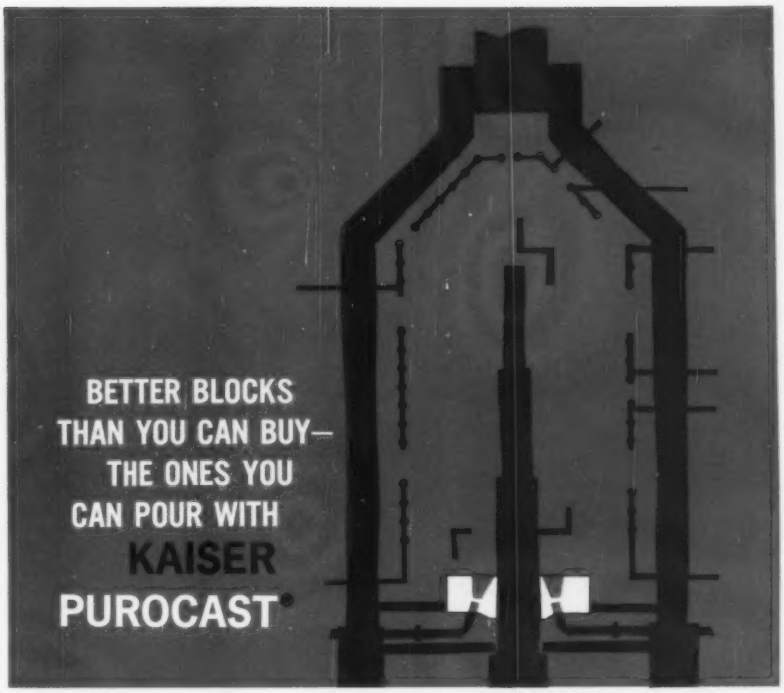
Gas Shielded-Arc Welding

"Gas Shielded-Arc Welding Processes" contains data from both published and unpublished material. Included in this small, authoritative book are: Gas Shielded Tungsten-Arc Welding, Gas Shielded Metal-Arc Welding (including CO_2 Welding), Cutting, Gases, Equipment, and Cost Data. The book is profusely illustrated and photographs, schematic diagrams or charts show every step of the way.

(AWS, *Gas Shielded-Arc Welding Processes,* American Welding Society, 33 W. 39th St., New York 18, N. Y., 76 pages, $1.50.)

Free Book Catalog

For a free copy of our book catalog write to BOOK DEPARTMENT, GULF PUBLISHING COMPANY, P. O. Box 2608, Houston 1, Texas. Often books reviewed here may be purchased from this source.



Kaiser Purocast castable is a better refractory material than you can normally buy in factory-fired burner blocks. Carefully blended low-iron, high-purity ingredients give it high resistance to spalling. Its high density—140 pounds per cubic foot—effectively reduces corrosive slag penetration.

The characteristic volume stability of Purocast makes it particularly suitable for high temperature burner blocks in the refinery oil heater.

Ask your Kaiser Refractories Sales Engineer how you can make all of your own burner blocks with Purocast—in your plant—and get these advantages:

Longer life without failure. Good uses of unassigned manpower to cast blocks in advance. Reduced inventory. Freight savings. And assurance that you can replace any shape block 24 hours after pouring—regain full heating in as little as 48 hours!

Call or write Kaiser Refractories & Chemicals Division, Dept. P6011 Kaiser Aluminum & Chemical Sales, Inc., at any of the offices listed below:

KAISER REFRACTORIES

PITTSBURGH 22, PA. . . . 3 Gateway Center
MEXICO, MISSOURI . . . Mex-R-Co Building
OAKLAND 12, CALIF. . . 300 Lakeside Drive

Mexico Refractories now merged with Kaiser Refractories

KAISER REFRACTORIES, DEPT. P6011
KAISER CENTER, OAKLAND 12, CALIFORNIA

Please send me information about Kaiser Purocast with instructions for casting and curing burner blocks

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

For more data on advertised products, use Readers' Service Cards, last page.

How to Do It...

Crane operator . . .

lowers inspector . . .

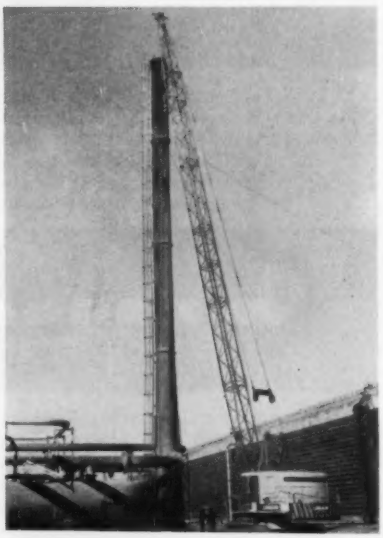
New Way to Inspect Inside of Stack

A crane and three men played key roles in inspecting the inside of a blow down stack on a thermal cracking unit at American Oil Co.'s Texas City refinery. A bosun's chair was rigged to the crane shown in the picture (right) and the chair was dropped down the 120-foot stack.

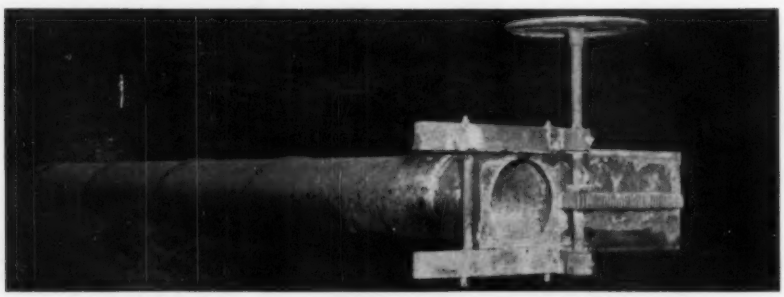
The procedure is simple. The inspector rides up in the chair, checking the stack's interior. He then rides back down again and gets out. In the upper left photo the crane operator communicates with the inspector, using earphones and a chest mike.

In the upper right, the inspector is shown at the top of the stack.

This item appeared originally in *The Amoco Texan,* American Oil Co.'s Texas City company paper, February 5, 1960, issue.



with this crane



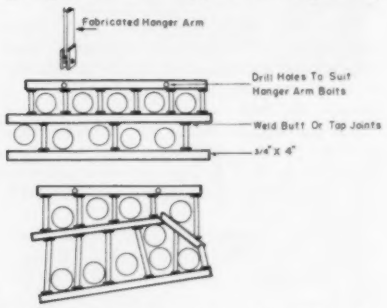
Slide Valve for Simple Tank-Dike Control

One refinery superintendent replaced all of the "grasshopper legs" on his tank dikes with this neat appearing slide valve. The flat gear on the sliding door can be purchased in many sizes, and the gear wheel comes to match. The welder measures the pipe ends and makes a plate to fit. He then makes the sliding valve to fit tightly on this plate when it is closed. With these valves hanging on the ends of the pit discharge lines, it is easy for operators to tell if the valve is opened or closed.

Make Your Tube Supports And Cut Tube Replacements

A large percentage of the present day tube still and cracking oil heaters are fired with sludge oil or combination fuel-gas and sludge-oil burners. Costly replacements of tubes and intermediate tube supports has been necessary because of corrosive attack caused by vanadium pentoxide and sodium salts in the sludge oils.

In many instances these supports are designed by the manufacturer to support as many as ten tubes in a group with the support casting being

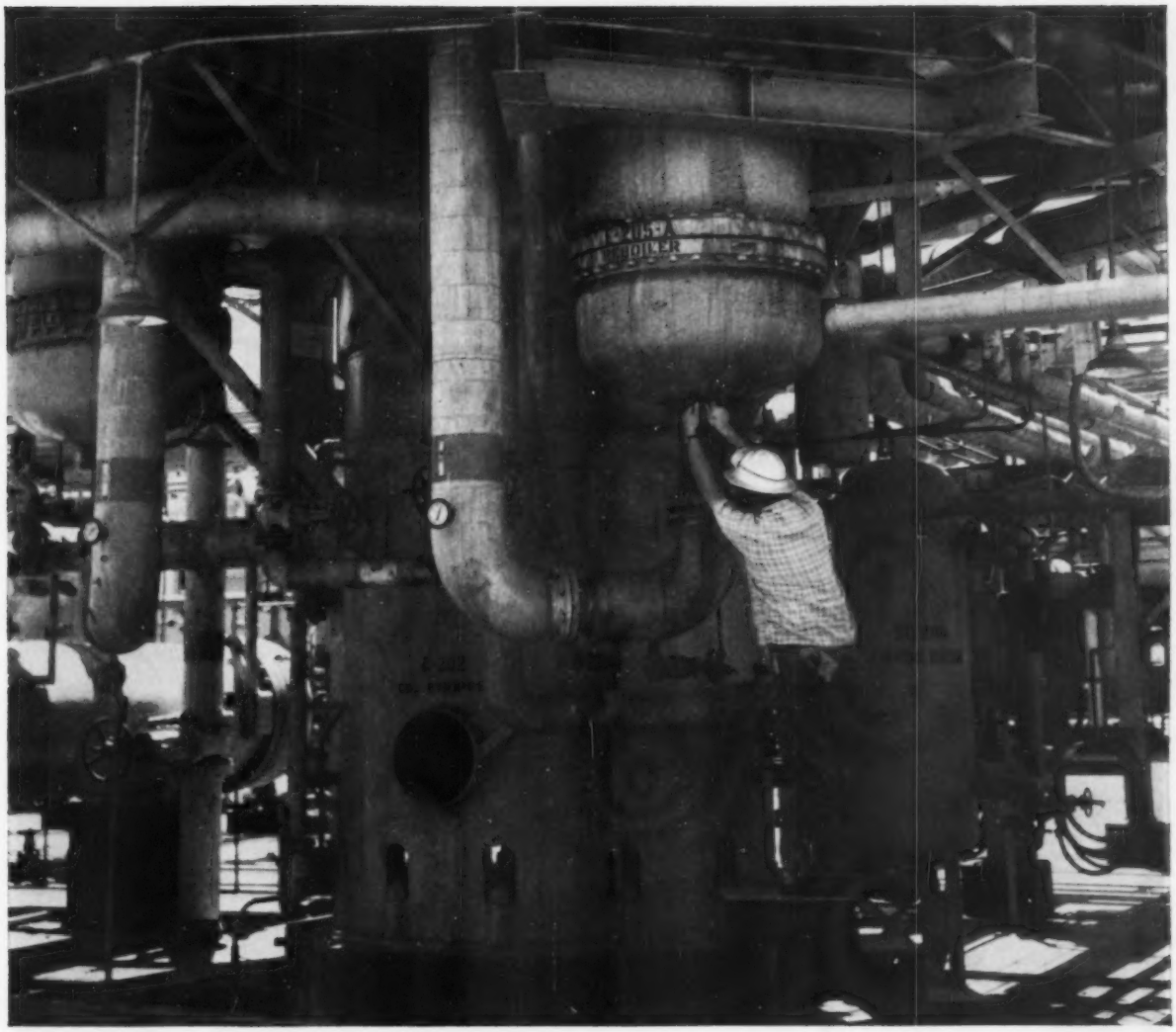


fabricated as a single casting. This design does not permit support replacements without sacrificing good tubes. A good many tubes have been prematurely sacrificed to permit new support installations.

A very simple, quick and economical method has been used with satisfactory results for the past ten years in the Mobil Oil Co. refinery, Paulsboro, N. J.

By using type 309 or 310 alloy bar stock (¾ × 4 inch and ¾ × 2 inch) and 25/20 welding electrodes, any support can be fabricated in the heater to suit the conditions of many sagged tubes. Thus, the practice of tube sacrificing is stopped and a good support can be made. The same alloy bar stock can also be used to fabricate hanger arms for the supports. Bolt holes must be drilled clean and preferably countersunk to eliminate sharp edges.

Some mild steel tubes of small



Monel alloy MEA reboiler tubes in 6th year ...show excellent resistance to CO_2 attack

This is a progress report. Late in 1954 Shell Chemical Corporation installed Monel* alloy tube bundles in the MEA reboilers at their anhydrous ammonia plant in Ventura, California.

The reboilers strip CO_2 from the "fat" MEA solutions that purify the hydrogen stream. The original mild steel tubes lasted from three to nine months. Shell then tested some chromium alloy tubes (i.e. 5% Cr, 0.5% Mo, 12% Cr, 0.5% Mo) but these were only marginally better than the mild steel tubes. Then Monel alloy tubes were tried. These have now been in use for well over five years. They show almost negligible corrosion.

The aqueous gas treating solution contains 17% (wt) of monoethanolamine and 2% (wt) CO at a pH of 10-10.5. Temperature ranges from 230°-240°F. Flow rate is 10-15 ft/sec.

Are you treating corrosive gases?

Do you select materials for amine gas treating systems? Tell us about your corrosion problems. We may be able to help you. The Huntington Division has made extensive plant and laboratory studies of corrosion problems with the various ethanolamines.

*Inco trademark

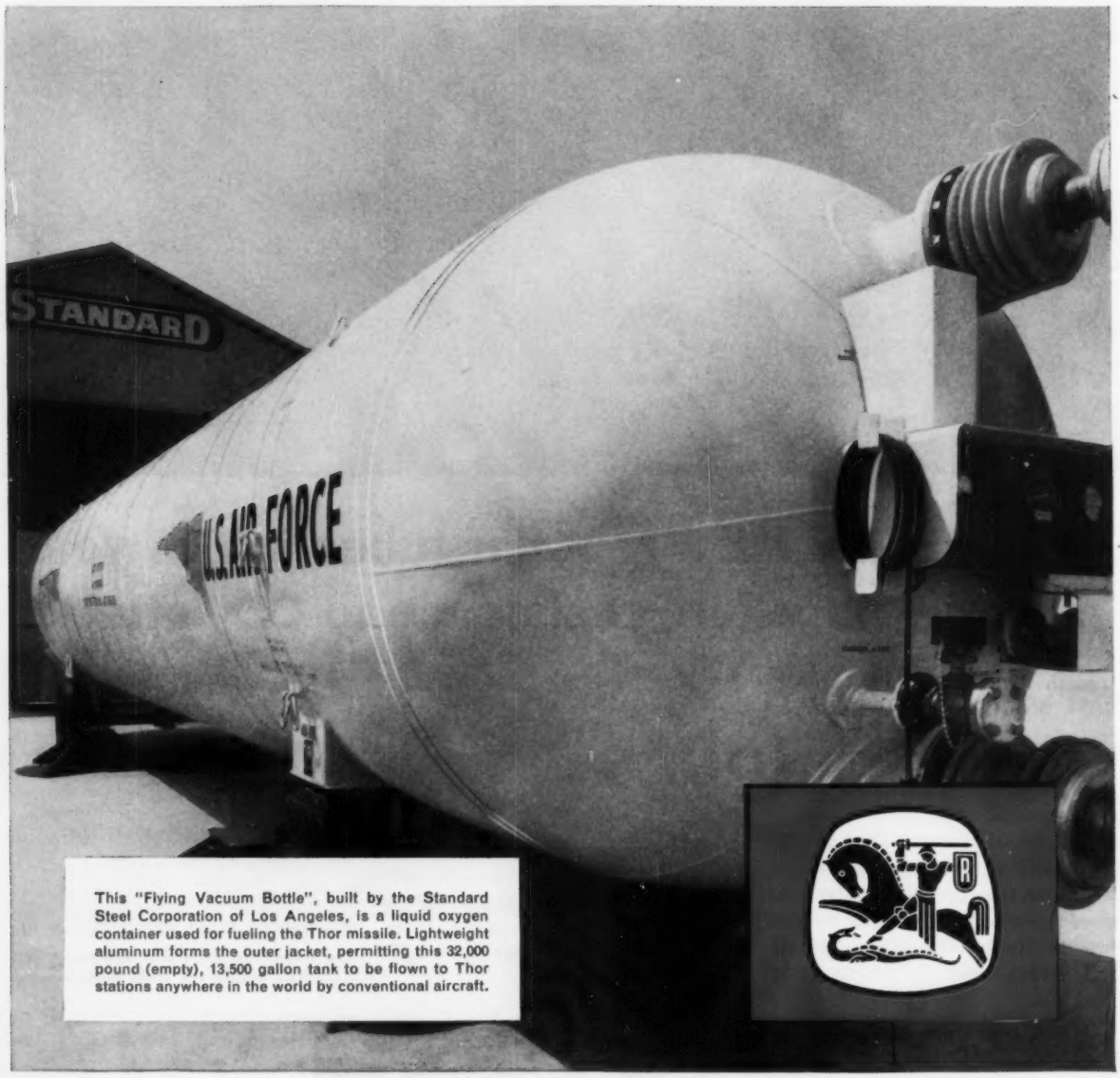
HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17, West Virginia

MONEL®

For more data on advertised products, use Readers' Service Cards, last page.

Aluminum Tanks and Vessels cost far less

...than those made with other corrosion-resistant metals!



This "Flying Vacuum Bottle", built by the Standard Steel Corporation of Los Angeles, is a liquid oxygen container used for fueling the Thor missile. Lightweight aluminum forms the outer jacket, permitting this 32,000 pound (empty), 13,500 gallon tank to be flown to Thor stations anywhere in the world by conventional aircraft.

The major costs of tanks or vessels are for initial materials and subsequent maintenance—and aluminum is the one corrosion-resistant alloy that offers big savings in both. It is corrosion-resistant in most atmospheres and, it's easy to keep clean. Yes, aluminum costs less, far less, and here are more reasons why:

CORROSION-RESISTANT

Aluminum resists corrosion from most process liquids. *Hydrogen peroxide, petroleum products, acetic acids, nitric acids, nitrogen solutions, turpentines, lacquers, beverages, sulphur-bearing gases*—all, and many other corrosives, can be handled in aluminum tanks and vessels without contamination or corrosion. Climatic conditions and atmospheric gases normally do not affect aluminum. Flammables may be safely stored in aluminum tanks and vessels, for aluminum is non-sparking.

LIGHTWEIGHT

Aluminum weighs just one third as much as steel. This can often mean lower fabricating costs. And it can result in other important cost reductions, from the initial purchase through handling, shipping and fabrication, to final installation.

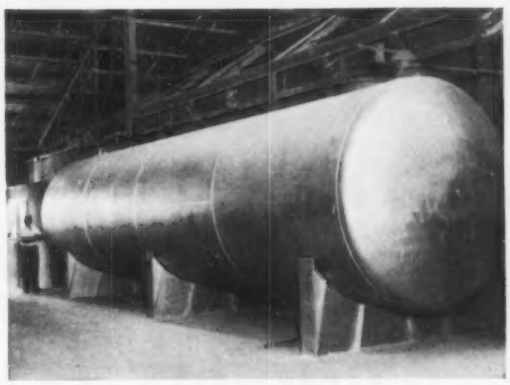
EASY TO FABRICATE

Tanks and vessels require high quality welding . . . and aluminum is an exceptionally easy-to-weld material. In fact, welds of comparable strengths can be made five to eight times faster on aluminum than on most other metals! Brazing equally well, it is also one of the most formable, most economical metals to work with.

EXCELLENT THERMAL CHARACTERISTICS

Reflecting up to 95% of radiant heat, aluminum provides superior protection for volatile chemicals. And aluminum's high thermal conductivity speeds the transfer of heat.

This giant aluminum tank holds ammonium nitrate solution. Non-sparking aluminum gives extra-long service under constant exposure to corrosion, with a minimum of maintenance.



Highly corrosive nitrogen solutions are safely stored in this tank made of Reynolds Aluminum for quick, local service to farmers for use in soil treatment.

LOW TEMPERATURE PROPERTIES

Aluminum, due to its excellent mechanical properties and low cost, is the ideal material for handling low temperature liquids such as *liquefied oxygen, nitrogen, methane*, etc.

IN USE EVERYWHERE

Aluminum is finding wider and wider use in the processing industry because no other metal offers so many benefits at such large savings. To learn how Reynolds Aluminum can help you, or for technical service, call your local Reynolds office or write *Reynolds Metals Company, Box 2346-CT, Richmond 18, Virginia.*

Write today for Reynolds Free Brochure on Aluminum Tanks and Vessels

REYNOLDS ALUMINUM

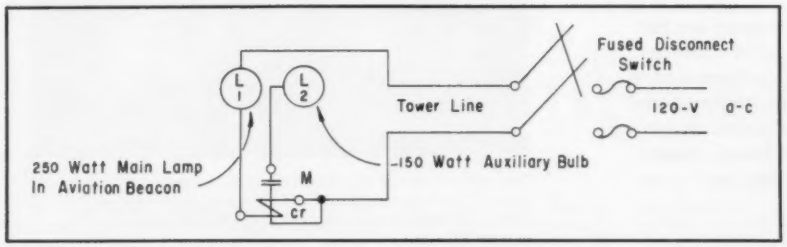
RICHMOND 18, VIRGINIA

Watch Reynolds new TV shows: "ADVENTURES IN PARADISE," "BOURBON STREET BEAT" and "ALL STAR GOLF"—ABC-TV

For more data on advertised products, use Readers' Service Cards, last page.

diameter are so cheap that this method of repair is not economical. However, in most cases a group of ten tubes of four inches to eight inches in diameter, or 4-6 percent chrome, or nine percent chrome-steel, are quite expensive and this repair method is strongly favored.

This item was submitted by Alexander Klinshaw, Mobil Oil Co., Paulsboro, N. J.



Warning Light Is Designed to Fail-Safe

One organization is required to maintain air traffic lights from sundown to sunrise by order of the federal government. Through the years it has learned how to spare night men the dangerous job of climbing the caged ladder-way to replace a burned-out bulb in wind and rain storms.

The innovation consists of installing a series relay coil in the 250-watt, main beacon-lamp circuit, with the normally open contact as shown in the diagram. The relay winding has approximately a six-volt drop through the enameled wire turns. The power supply is through a fused switch located in the security-guard dispatcher's office where a view of the beacon is uninterrupted. Under normal conditions, with the 250-watt unit "On," the relay is energized "Open." This means that the auxiliary lamp is deenergized. With failure of the main filament, the relay is deenergized, the contacts close, and the 150-watt auxiliary lamp in placed in the circuit automatically.

The decision to use a 150-watt auxiliary was not by capricious happenstance. Night trials proved that it required a 100-watt differential in brilliance to alert the guard officer that the standby lamp was in the circuit. This is a signal for the guard to telephone the night maintenance supervisor and tell him to enter the fact in the daily log. Subsequent action is then taken by day forces when weather permits.

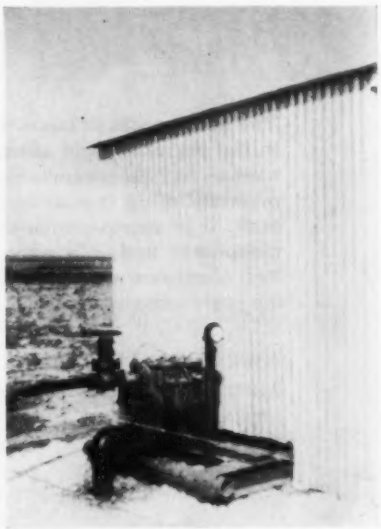
This idea was submitted by Warren Cross, Oak Ridge, Tenn.

Buggy Unloads Easily With Pipe Pallet

The safest way to move pipe inside the refinery yard is with a pipe or straddle buggy. After moving the pipe from the storage yard to the refining-unit area, a temporary storage pallet is needed.

One refinery foreman made the pallet shown in the photo out of three and four-inch pipe. The four-inch pipe is used as a base and the three-inch pipe as cross members. The ends of the three-incher are covered with a piece of angle iron to provide a square shoulder for flaps of the straddle buggy to hook into. Two-inch posts along the ends of the cross members keep the pipe from rolling off while the pallet is being loaded.

This idea was submitted by Harry Hess, Dallas, Texas.



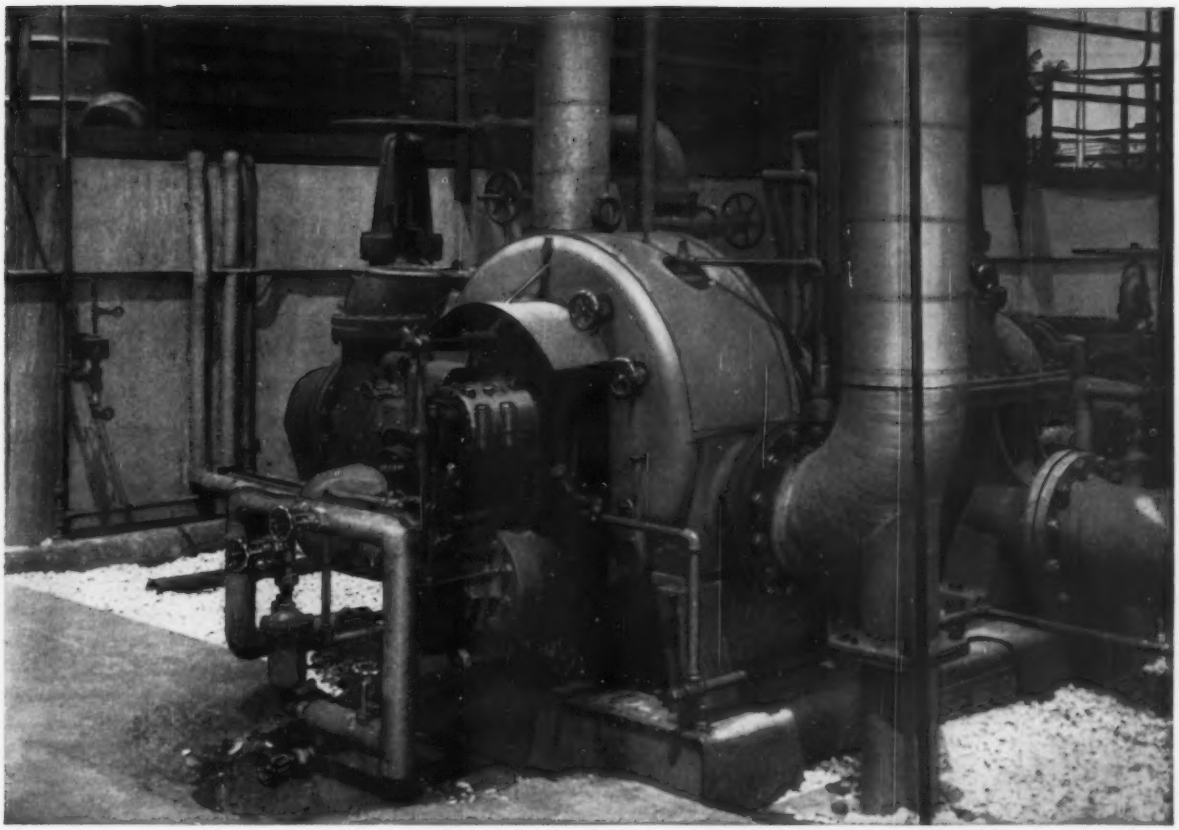
Fire Hazard Cut by Putting Pump Cylinder Outside

Where skid-mounted pumps are used to pump oil into high pressure units, the building may be built over the pump in such a manner that all of the high-pressure fittings and pump cylinders are outside of the building. Then, if a cylinder, valve cover or fitting should rupture, the volatile fluid cannot reach the power unit and cause a fire.

After the skid-mounted pump has been set and the inlet and discharge connections made, the house is built so that the side of the building makes a fire wall between the engine and the pump. The pumper then has space for a desk in the engine room and yet is still away from any fumes that may leak from the pump.

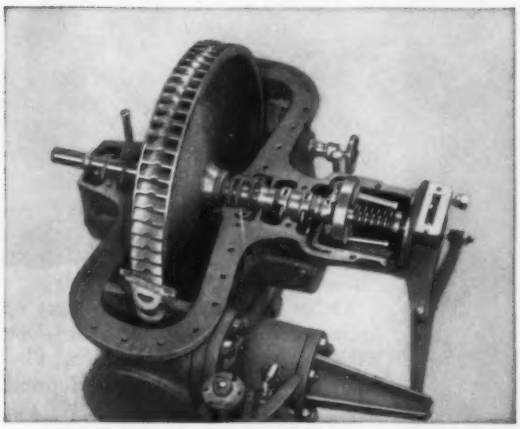
YOUR IDEAS ARE VALUABLE!

At least $10 will be paid for each idea accepted for "How to Do It." Just send a brief note with a photo or sketch to the Editor, *Petroleum Refiner*, P. O. Box 2608, Houston.



TERRY SOLID-WHEEL TURBINES

used exclusively at Baton Rouge plant of W.R.Grace & Co.



The upper photograph shows one of the 17 Terry turbines installed at the Baton Rouge, La., GREX high-density polyethylene plant of W. R. Grace & Co. Above, a typical Terry solid-wheel turbine with cover removed to show the wheel construction.

In purchasing equipment for their new 50,000,000-pound high-density polyethylene plant, W. R. Grace & Co. standardized, wherever possible, on a single source of supply for each type of equipment used. Consistent with this policy, Terry steam turbines were used exclusively throughout the utility and process sections of the plant.

A total of 17 turbines were placed in service for driving pumps and fans. These are all of the solid-wheel type, ranging in capacity from 50 to 240 HP.

Terry solid-wheel turbines are known for their long life and sure dependability under the most-trying operating conditions. They feature a single-piece wheel which is virtually indestructible.

Send for details of these trouble-free turbines. Ask for a copy of bulletin S-116.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

TERRY

TT-1214

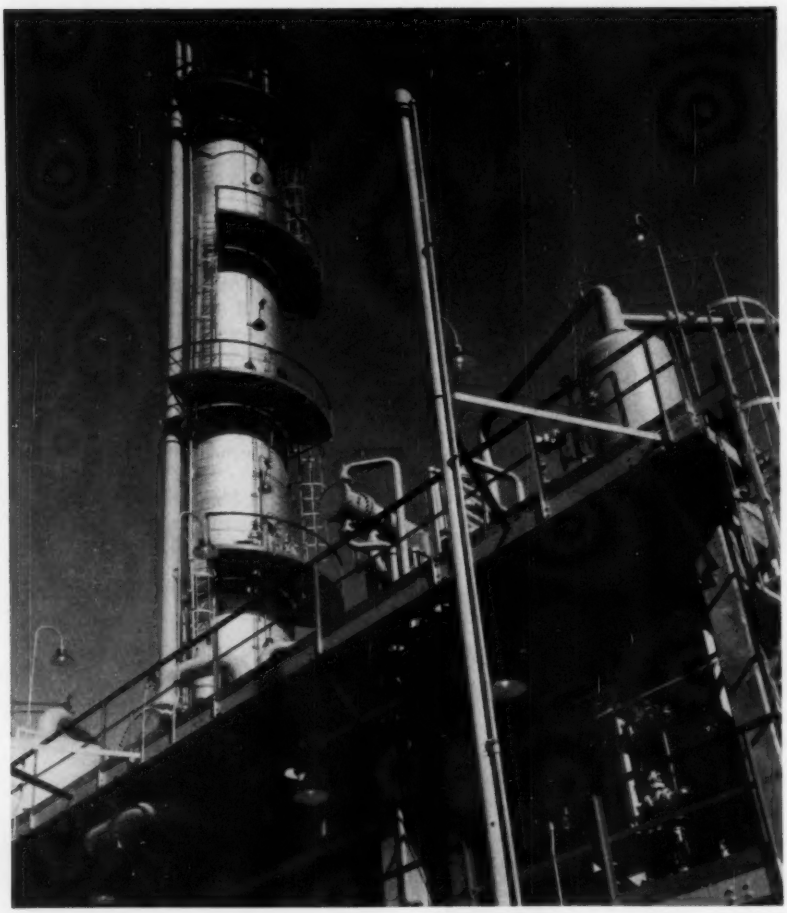
For more data on advertised products, use Readers' Service Cards, last page.

Who's Building...

Humble Scores Big with Polypropylene

New 40-million-pound-per-year unit is first to employ large-scale continuous process. It can later be expanded to 100 million pounds per year

A 40-million-pound-per-year polypropylene plant was formally opened May 10 at Humble Oil & Refining Co.'s Baytown, Texas, refinery. It was designed, engineered and constructed by the Humble staff. The largest installation of its type in the world, the new $30-million plant occupies an area equal to three city blocks. Initial capacity of the big unit, which can later be expanded to 100 million pounds per year, will involve a large part of current national production of polypropylene. This plant marks the first time polypropylene has been manufactured on a large-scale continuous process basis.



Big Baytown polyolefin unit involves investment of about $30 million.

Of the $30 million invested in the new plastics venture, $15 million was for research and development. Humble uses the Ziegler catalyst process which it developed into a method designed to operate 24 hours a day. This process was tested in a 1-ton-per-day pilot plant at Esso Standard Oil Co.'s Baton Rouge refinery. The plant culminates a three-year master plan that began with basic research on catalysts and chemical reactions.

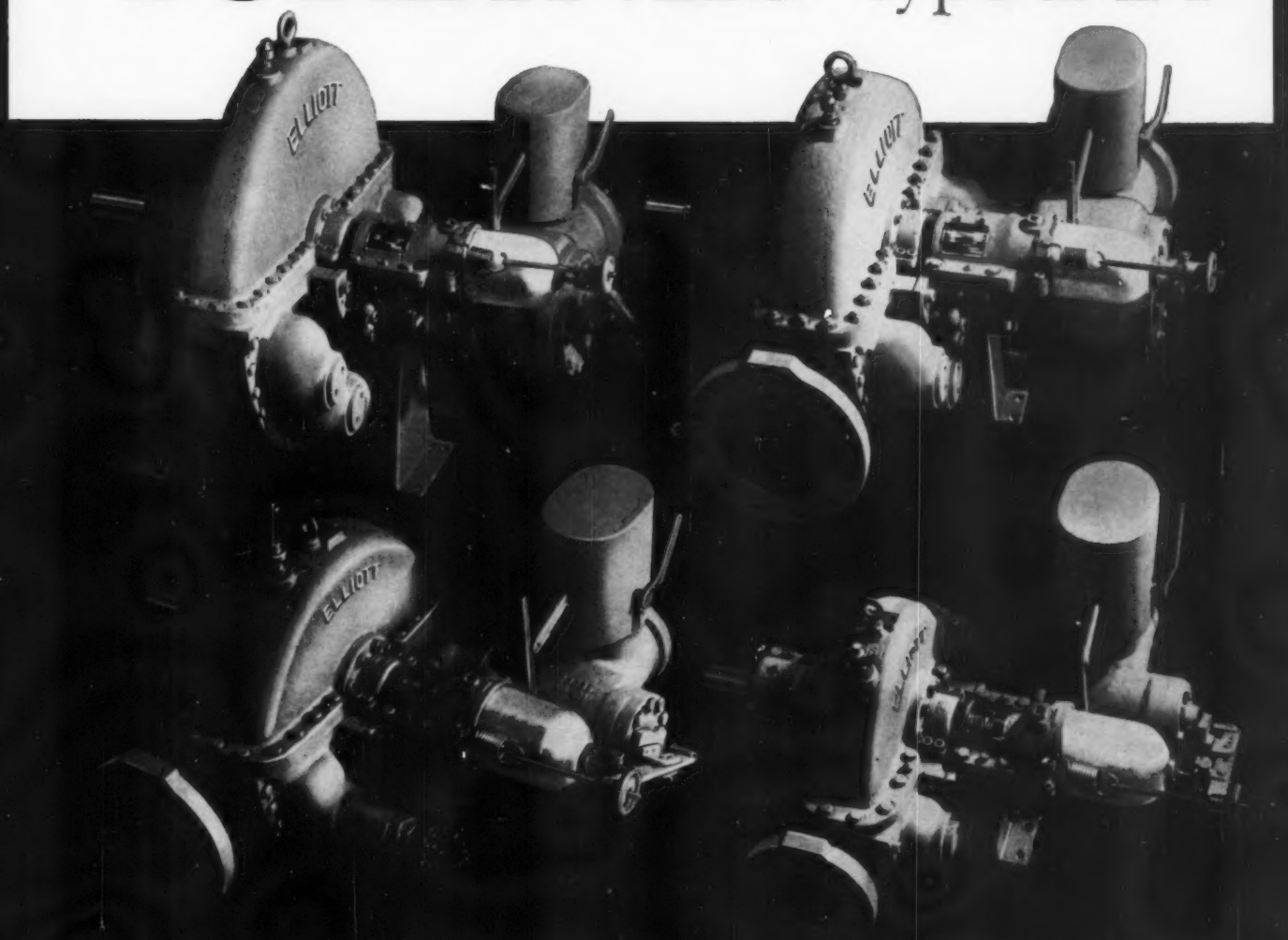
Dr. R. E. Wood, Esso Research Laboratories associate director, pointed out that in addition to the continuous operation feature, a key aspect is an improved catalyst invented by Esso Research chemists. The plant itself is the largest "grass roots" polypropylene facility yet constructed.

Polypropylene has been in commercial production for about 2½ years. It is produced by AviSun Corp. (currently building a 100-million-pound-per-year plant on the East Coast), and Hercules Powder Co. However, Humble is the first company to come up with a unit for large-scale continuous manufacturing.

Other companies plan to start up units by the end of this year—Dow Chemical Co., Bay City, Mich.; Firestone Tire & Rubber Co., Hopwell, Va.; Montecatini Co., Neal, W. Va., and Texas Eastman Co., Longview, Texas.

Molded polypropylene items are both durable and attractive. Films for packaging and wrapping are clear but glossy and tough. Various end-uses foreseen include synthetic fibers and piping materials, and many other potential polypropylene products are

ELLIOTT mechanical drive TURBINES type YR



STURDY!
WEATHERPROOF!
DEPENDABLE!

All-weather protection, standard for Elliott type YR turbines, assures dependable operation under all conditions of heat, cold, moisture, dust and contaminated atmosphere.

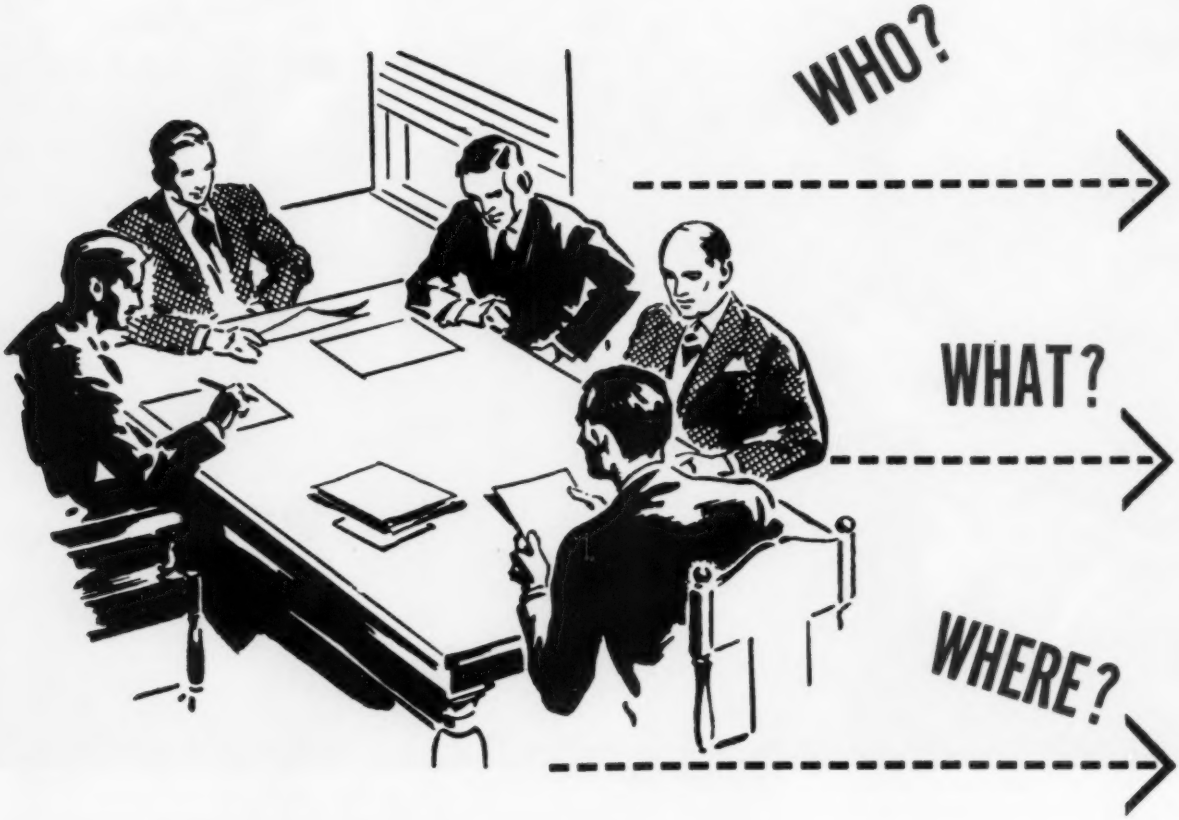
The direct-acting speed-governing system is simple and positive, available in several modifications to match speed and pressure requirements. The rugged rotor assembly is dynamically balanced. Bearings and shaft seals are readily accessible for maintenance. Hand valve reduces steam consumption at partial loads.

Many other features contribute to the dependable and economical performance of Elliott type YR turbines. Write for complete details to Turbine Division, Elliott Company, Jeannette, Penna.

ELLIOTT Company
Jeannette, Pennsylvania

HO-1

With Men



REFINERY CATALOG

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Who Buy And Specify

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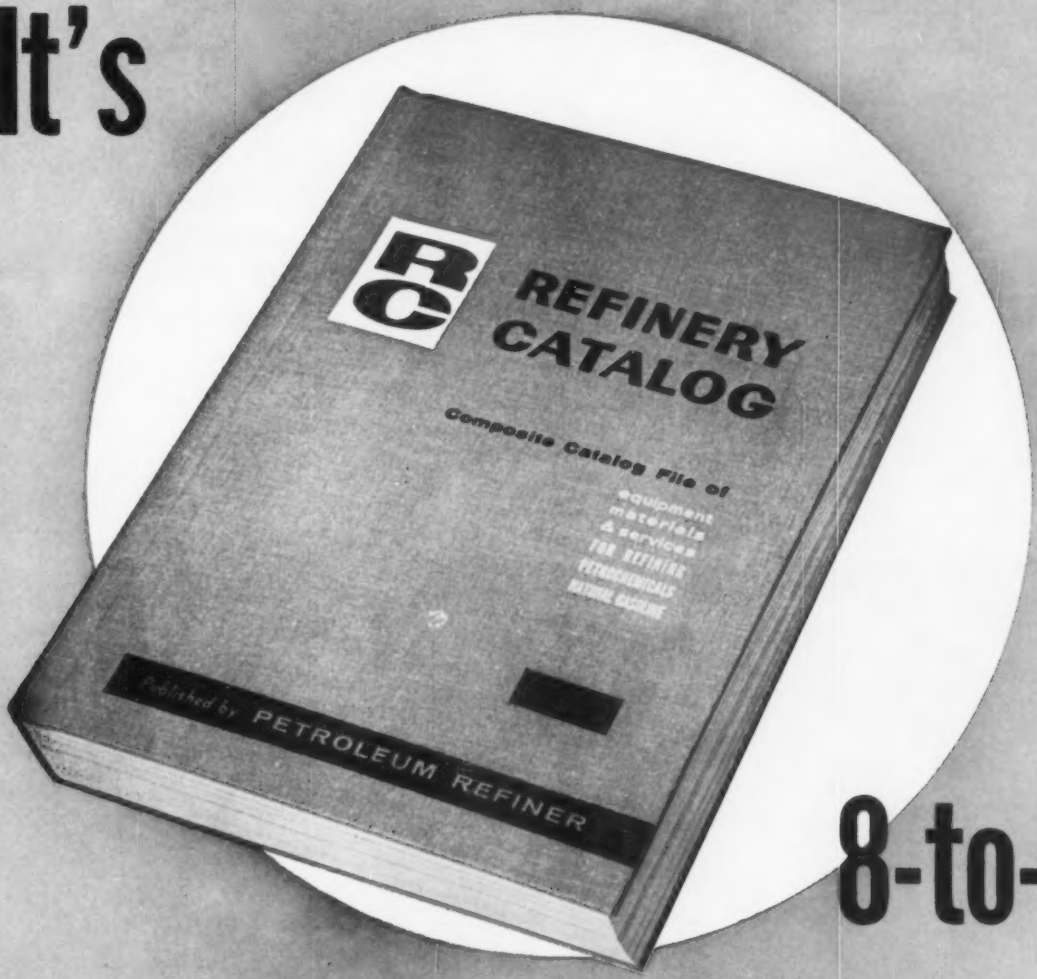

8-to-1

Look to REFINERY CATALOG for quick answers to your procurement problems in the refining, natural gasoline and petrochemical industry. It's indexed and cross-referenced to save time and eliminate error in planning, buying and specifying for this fast-moving market. That's why buyers and specifiers express a preference of 8-to-1 for REFINERY CATALOG over individual product catalogs.

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being studied.

Polypropylene retains its basic shape up to 290° F. It will not melt until the temperature reaches 335° F.

At opening ceremonies, R. M. Jackson, chemicals coordinator for Jersey, noted that Humble's revenue from chemical sales last year was $250 million and he predicted a higher rate in 1960. He said petrochemicals demand was increasing at a rate of about 10 percent a year.

Alexis Voorhies, Jr., director of Esso Research Laboratories, said about 25 percent of Jersey's research concerns chemicals.

Gilsonite Plant to Double Its Capacity

Within less than three years from the time it started up, the world's first commercial refinery for producing gasoline and high-purity metallurgical coke from a solid ore is undergoing an expansion. The project will almost double capacity by late this spring.

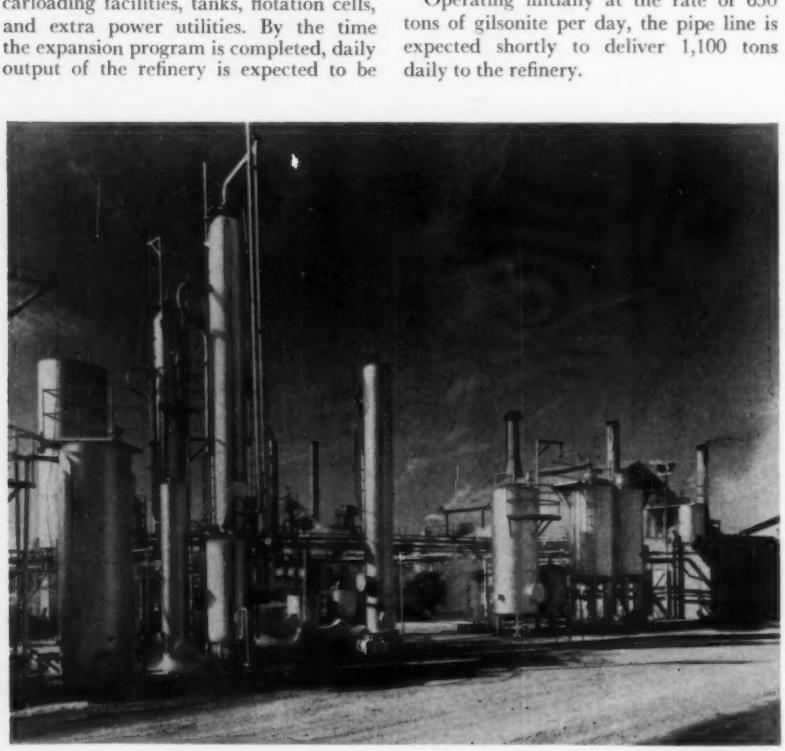
American Gilsonite Co.'s unusual refinery near Grand Junction, Colo., has undergone a second expansion program since its erection in August 1957.

The increased refinery capacity involves additional slurry de-watering facilities to reduce the water content of the slurry from the pipe line. Additional major equipment being installed includes another coking furnace, a third steam boiler, an additional railroad spur from the Denver & Rio Grande Western Railroad, tank carloading facilities, tanks, flotation cells, and extra power utilities. By the time the expansion program is completed, daily output of the refinery is expected to be 1,600 barrels of gasoline, 1,300 barrels of railroad fuel, and 350 tons of coke.

The latest expansion is the result of an investigation by the Denver & Rio Grande Western Railroad into the possibility of using a gilsonite-source fuel. Feasibility of using the fuel for diesel engines was established after a year-long study by both the research and operating departments of the Rio Grande.

The conversion of gilsonite ore—a solid hydrocarbon asphaltite—into high-octane gasoline and other fuels as well as calcined coke for the metallurgical industry, was fathered by American Gilsonite. Gilsonite ore, mined near Bonanza, Utah, close to the Colorado state line, is transported as a slurry by a 72-mile pipe line to the refinery near Grand Junction. There it is de-watered and converted to liquids and coke.

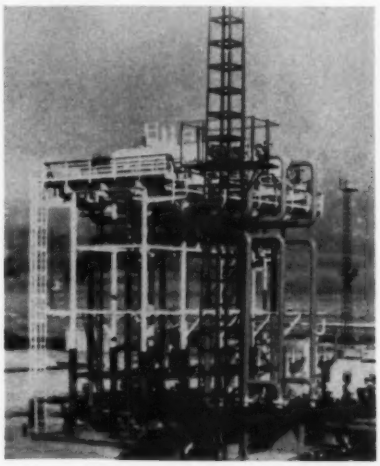
Operating initially at the rate of 650 tons of gilsonite per day, the pipe line is expected shortly to deliver 1,100 tons daily to the refinery.



This 500-bpd Merox unit has been put in operation at Pana Refining Co., Pana, Ill., treating thermal gasoline. The unit performs the dual function of mercaptan extraction and sweetening and is a conversion of a regenerative caustic scrubbing unit and a copper treating unit.

Crude Stabilization Plant Will Expand in Algeria

Construction work is being carried forward rapidly on the expansion of a crude oil stabilization plant at Hassi Messaoud, Algeria, to increase output to 100,000 barrels of crude from the Sahara oil fields



of the Compagnie Francaise des Petroles (Algerie).

Initial components of the plant, located 420 miles southwest of Algiers and designed and built by Stone & Webster Engineering Corp., are already producing 54,000 barrels daily.

Crude oil from Hassi Messaoud is transported through a 24-inch, $100-million pipe line to the port of Bougie on the Mediterranean coast. There it is loaded on tankers for refineries on the southern coast of France.

An unusual feature of the plant design was the effective removal of very large quantities of wild gas from the well fluids. Retained were maximum practical amounts of stabilized crude oil. Presently the separated gases, totaling 75 MMcf per day, are being flared because of no immediate markets. However, a portion may be recovered ultimately by removal of liquefied petroleum gas, and the balance of the gas may be returned to the wells for conservation purposes. The gas will also be used in gas turbines to produce the total electric power requirements of the field.

Ashland Oil & Refining Co. plans to increase by 25 percent the capacity of its proposed commercial hydrodealkylation plant. It will build the unit near the company's largest refinery, at Catlettsburg, Ky. There, favorable normal weather conditions during the winter period of construction will permit the earliest possible completion. The unit is scheduled to go on stream before March 1961. The Catlettsburg unit will have an anticipated production capacity of 75 million pounds per year of naphthalene and 15 million gallons per year of benzene.

The company had originally announced plans to construct the first Hydeal unit at its Buffalo, N.Y., refinery (see February issue, page 178). Relocation of the

what's your best estimate?

...a quiz for Petrochemical Executives who want to keep posted'

QUESTION 1. In 1959, 28 plants in the United States were producing ethylene—the hydrocarbon intermediate which is way ahead of all others both in quantity produced and in versatility. What was the estimated total U. S. capacity for this valuable chemical in 1959?

a — 3.7 Billion Pounds

b — 4.9 Billion Pounds

c — 5.6 Billion Pounds

d — 6.4 Billion Pounds

QUESTION 2. How many of the U. S. ethylene plants were designed, engineered and constructed by the Lummus Company?

	PLANTS	CAPACITY
a	3	.4 Billion lbs.
b	5	.6 Billion lbs.
c	7	.8 Billion lbs.
d	9	1.0 Billion lbs.

ANSWERS: 1. *The answer is (c)—5.6 billion pounds, according to* Chemical Week's *Report on Ethylene, May 9, 1959.*

2. *Again the answer is (c). In the last 10 years Lummus has 7 Ethylene plants to its credit in the U. S. alone with a combined capacity of .8 billion lbs. Lummus' world-wide total is 13, with a combined capacity of over a billion pounds per year. For ethylene projects, or any type of process plant, call on Lummus' 50 years of experience in design, engineering and construction.*

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(*"Income Quotient")

Design Economics of Heat Exchangers Furnish Basis for Heat Transfer Cost Engineering

The application of cost engineering practices in the accurate evaluation of capital equipment in the process industries is rapidly becoming more and more vital to the management of process companies, as margins of profit grow narrower.

Management now depends increasingly, therefore, on modern cost-engineering practices to evaluate realistically the true, long-range economy of a given piece of equipment in relation to its initial cost, cost of installation, maintenance, operation, labor, replacement — and in relation to the productivity or profit of the process involved.

The importance of efficient, practical, long-range forecasting is increasingly a focal point in the process industries as a whole, but no where is it more important than in the purchase and operation of heat exchangers for use in continuous flow processes, where the operation of the unit never ceases, and therefore must be calculated on a basis of maximum longevity, efficiency and service. Included in the design of each heat exchanger must be a consideration of its initial cost, its cost of installation (including piping, fittings, valves, flanges, etc.), its operation and maintenance (including corrosion-protection, mechanical maintenance, cleaning, re-tubing, replacement parts) — and the factor of labor costs attendant to the installation, operation, maintenance and/or replacement of the unit.

In each case, however, the basic factors must be considered and determined: capital, overhead, maintenance and unit process costs.

The Cost Engineer, therefore, must be committed to continual study, re-examination and revaluation of every area which contributes to the practice of chemical engineering, for it is from his fundamental and technical knowledge of the process involved that his eventual forecasts for productivity, efficiency and longevity must ultimately spring.

Considerable thought has been given to the "ideal" background or qualifications for the Cost Engineer. Certainly his primary requisite must be a thorough knowledge of chemical engineering, including, in the heat transfer field, an equally intimate grasp of the thermal and metallurgical engineering so vital to an understanding of heat exchanger design economics.

Secondly, he should have had practical experience in the production phases of the chemical business. Thirdly, he will be better equipped to understand the complexities of the "business" side of such evaluations, if he has had education and/or experience in a certain amount of business administration.

Clear, concise, understandable communications is another factor of great importance to the ultimate success of the Cost Engineer, for he must transmit his findings, make his recommendations and defend his decisions to a number of widely varied types of people, some with technical background and others with little or no technical knowledge.

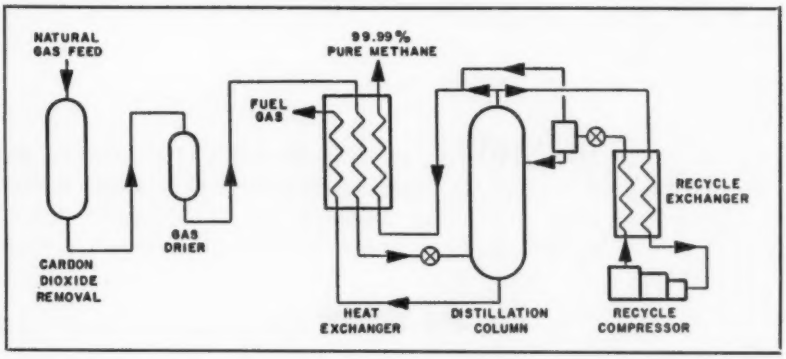
The Cost Engineer must be tireless on detail, inquisitive at each point, yet tactful in his demands on subordinates and associates. Above all, although cost engineering presents a real challenge to his analytical mind, he must serve his purpose with genuine humility, cognizant of the amount he has yet to learn.

In short, he should have a proclivity towards the functions of management, for that is where he might very well be headed.

(FOOTNOTE: For more detailed information on this subject, write for your free copy of "Cost Engineering" to WESTERN SUPPLY COMPANY, HEAT EXCHANGER DIVISION, P. O. BOX 1688, TULSA, OKLA. — and for immediate assistance on heat transfer cost engineering, feel free to suggest our services . . . whether or not there's a heat exchanger in your company's future!

Building . . .

unit to Catlettsburg and a substantial increase in capacity is based on completed contracts covering 80 percent of rated plant capacity. The company indicated that concurrently with construction of the unit at Catlettsburg an additional plant is being considered for Buffalo to produce 10 million gallons per year of benzene. The Buffalo plant could be converted to naphthalene production later through addition of naphthalene recovery facilities.



Allied Adds Methane Purification Unit

A methane purification plant of the low-temperature type was shipped recently to Allied Chemical Corp., at Moundsville, W. Va. The new facility, which incorporates a high degree of on-stream reliability, was designed and built by Air Products, Inc., to refine methane-rich natural gas into ultra-pure methane.

Allied will use the 99.99-percent-pure product to make chlorinated hydrocarbons such as carbon tetrachloride, chloroform, methyl chloride and methylene chloride. The process equipment, which operates at very low temperatures, is contained in a single compact "cold box." This compactness is possible because processing methane at liquid temperature requires only a fraction of the space used in the warm type of purification process.

In the plant's process, methane-rich feed gas enters a caustic scrubber for the removal of CO_2. The feed gas then enters one of two alumina-filled drier vessels. While one drier vessel is in use, the other is reactivated. Alternation of the drier vessels is automatic. The dried feed is then cooled in the heat exchanger by outgoing fuel gas and pure methane product from the column.

Leaving the heat exchanger, the feed gas goes through an expansion valve where it drops in temperature, and then enters the distillation column. Here methane is separated from the heavier hydrocarbons. Pure methane is taken from the top of the column as a gas. Heavier hydrocarbons are withdrawn from the bottom as liquid and passed back through the heat exchanger to recover the refrigeration.

Pure methane from the top of the column is divided into two streams. One stream is fed into the main heat exhanger where it cools the incoming feed stream and emerges as methane product at ambient temperature.

The other portion of the stream is passed through the recycle heat exchanger and is compressed by the recycle compressor. The high-pressure stream from the compressor then goes out through the recycle heat exchanger where it is cooled by incoming product. The methane is then expanded to form liquid for refluxing the column. The gas portion of the reflux stream is removed in the phase separator and joins the product stream from the top of the column.

El Paso Natural Gas Co. is planning a joint petrochemical production and marketing venture with Rexall Drug and Chemical Co. The project will include plants at Odessa, Texas, for the manufacture of olefins, polyolefins and chemicals. The first plants to be built are scheduled to begin production in early 1962 and will produce ethylene, propylene, conventional polyethylene, linear polyethylene and polypropylene. Initial capacity of the olefin plant will be in excess of 200 million pounds per year, and the combined capacity of the polyolefin plant will be in excess of 150 million pounds per year. El Paso Natural will furnish raw materials.

CATC, a group formed by Cities Service Oil Co., The Atlantic Refining Co., Tidewater Oil Co., and Continental Oil Co., has started what it terms "Operation Pig Squeal" at Baton Rouge, La. The operation started with construction of the largest unit of its kind for the recovery of gasoline, propane and butane from natural gas. Some 175-MMcf a day of offshore natural gas are expected to yield as much as 400 barrels of natural gasoline, plus separate streams of butane and propane totaling 600 barrels. This is to be done without appreciably shrinking the stream of natural gas that will flow

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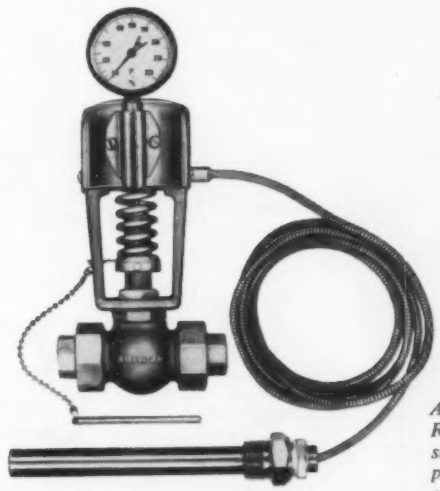

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The valve stem on American Temperature Regulators is sealed off by a friction-free bellows that makes practical a nonleaking packless valve. Also contributing to fast, stable action is the use of an extra-long preflexed adjusting spring. This spring permits a long range of temperature adjustment without disturbing valve sensitivity at normal levels.

There are other high-quality features in American Temperature Regulators: maximum use of stainless steel; standardized parts; the fewest possible components; and unitized assembly. In addition, compactness simplifies installation in "tight" locations.

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For more data on advertised products, use Readers' Service Cards, last page.

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Complementing these processes, Houdry also offers catalysts, technical service, engineering, research, and economic consultation.

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through pipelines to domestic and industrial consumers.

In a move akin to "getting the last squeal from the pig," CATC has purchased a large dry adsorption system from Delta Tank Manufacturing Co. based on the features of smaller units that have been in service in Southwestern gas fields since early 1957. Placed in operation at Grand Cheniere, La., early this year, the big unit consists of eight 20-foot-high towers. Four of them contain 60,000 pounds of palletized activated carbon made from selected petroleum products by National Carbon Co. The other four towers will contain silica gel and activated carbon for adsorption of heavier natural gasoline fractions (pentanes, hexanes, heptanes, and heavier).

Cuban Petroleum Institute plans to construct a 20,000-bpd refinery somewhere in the Havana or Ciefuegos areas of Cuba. The institute particularly has its eye on the Port of Casilda on the Bay of Ciefuegos. The plant would process crude oil from the U.S.S.R. under an oil-for-sugar trade agreement. Mexican and Egyptian sources are also under consideration. The Cuban government is also upping capacity of its Cabaiguan refinery from 2,500 bpd to 6,000. The plant processes Cuban crude oils and markets products in Cuba.

Cities Service Refining Corp. has started construction of a multi-million-dollar petrochemical plant at Lake Charles, La. It is designed to produce ortho-xylene at a rate of 120 million pounds per year. A contract has been entered into with Cosden Petroleum Corp. for sale of the plant's production for export through Cosden's exclusive agent, Fallek Chemical Corp., New York. Basic feed stocks for the new ortho-xylene plant will be supplied from present units of the Cities Service Refining at Lake Charles.

Continental Oil Co. has started construction work at Ponca City, Okla., on a $50,000 research facility to be used in evaluating plasticizers and other petrochemical products used in making plastics. The building will be of concrete-block construction and is expected to be completed in about one month. It will be constructed adjacent to Conoco's petrochemical pilot plant. When completed, the new laboratory will house equipment to make both small and large test samples of plastics in various forms.

The American Oil Co. has awarded a contract for construction of two new refinery units at Texas City to The M. W. Kellogg Co. They are:

- A 150,000-bpd crude-running unit, said to be the "largest in the world" (see May issue, page 288).
- A 47,600-bpd catalytic cracking unit.

The company is still taking bids on an alkylation unit with a 14,500-bpd capac-

For more data on advertised products, use Readers' Service Cards, last page.

Esso

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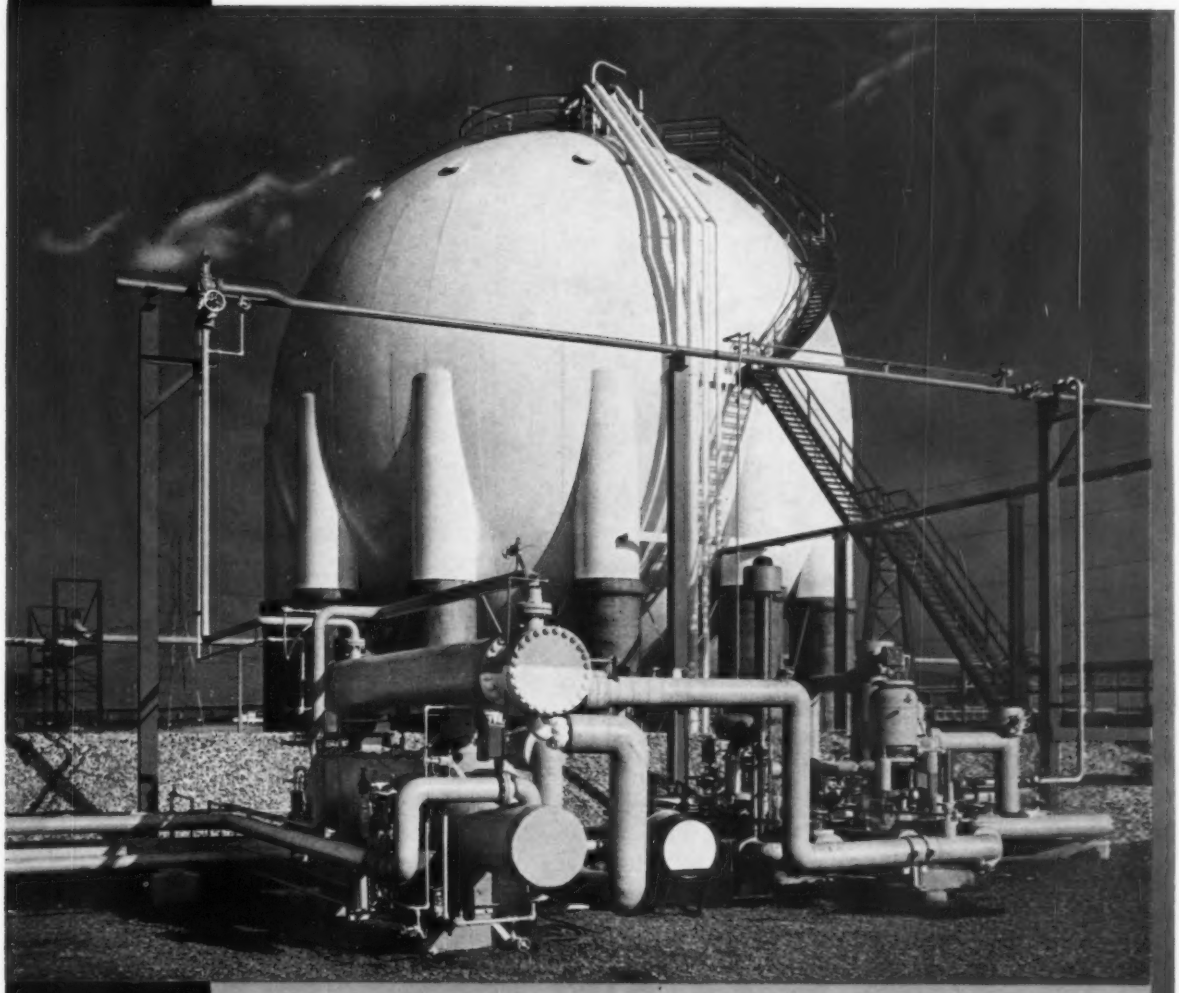

Stone & Webster's skill and experience have added long-term profitability to industrial plants all over the world.

The largest above ground facilities in the United States for the low temperature storage of liquid ethylene have been placed in service by Esso Standard, Division of Humble Oil & Refining Company at Linden, New Jersey. With this installation, Stone & Webster Engineering Corporation continues its leadership in the low temperature processing and storage of hydrocarbons and chemicals.

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See pages 1513 to 1516 of the Chemical Engineering Catalog for Distributor listing. Complete catalog information available on request.

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Building . . .

ity—also the largest of its kind in the world. Preliminary engineering work and engineering purchasing will start immediately for the crude unit and cat cracker, and actual construction probably will get under way late this summer. The two units are to be completed in the fall of 1961, and the entire modernization program by early 1962.

Mobil International Oil Co.'s Venezuelan affiliate has completed construction of a $30-million refinery at El Palito, Venezuela. The new facility, located on the Caribbean coast near Puerto Cabello, has a capacity of 50,000 bpd. It processes crude oil from Barinas Province, in Southwestern Venezuela, to which it is linked by a 210-mile pipe line. The refinery is designed to manufacture three grades of gasoline, kerosine, jet fuel, diesel oils, and heavy fuel oils. Some of the automotive fuels are sold through a service station network within Venezuela. A $2.5-million lubricant-blending plant, also at El Palito, is capable of supplying 100,000 barrels of lubricants annually for the Venezuelan market.

Elsewhere in South America, Mobil International affiliates have just completed a 150-bpd lubricant-blending plant at El Callao, Peru; will soon complete a blending plant at Vina del Mar, Chile, and within the next several months will begin construction of a blending plant in Colombia.

Shell Chemical Co. will triple its projected plant capacity for production of polyisoprene. This will involve construction at a midwestern location of an integrated monomer-polymer plant of 80 million pounds annual capacity. Hydrocarbon feedstocks for the unit will come from Shell's Wood River refinery near St. Louis. The Shell rubber has been manufactured commercially on a scale of up to five tons per day at Torrance, Calif., for slightly over a year. The California plant is currently being expanded to a capacity of 40 million pounds per year of polyisoprene with completion of construction expected this fall. The second installation, presently in an advanced stage of engineering design, will be on stream one year later.

Hungary has plans in the mill to double its chemical industry output—66 percent of the added capacity to be in fertilizers, plastic and synthetic fibers. The Tiszapalkonya plant will add 100,000 tons per year of nitrogenous fertilizers, and the Kazincbarcika unit will be doubled in size—changing from coke feedstock to natural gas. Tiszapalkonya also will add a 300,000-ton-per-year superphosphate plant and two new 100,000-ton-per-year sulfuric acid units. Borsod Chemical Combine will build a 15,000-ton-per-year polyvinyl chloride plant, and Tiszavidek Chemical Enterprise will construct a 10,000-ton-per-year polyethylene facility.

Runnels Gas Products Corp. and Texas Gas Exploration Corp., have awarded a joint contract to The Fluor Corporation, Ltd., to engineer, procure materials and construct additions that will double capacity of its gasoline plant at Eunice, La. Facilities that extract ethane and heavy hydrocarbons from natural gas by low temperature absorption will be doubled so that additional natural gas can be processed. Existing fractionation facilities will also be expanded to accommodate increased production from the extraction units. The additions are scheduled for completion early next year.

Solar Nitrogen Chemicals Co. plans to build a new $15-million ammonia plant near Joplin, Mo. Construction is scheduled to start in the near future, with completion expected in about one year. The plant, which will produce anhydrous ammonia, urea, and related products, will be operated by Atlas. Production will be marketed by Sohio Chemical Co., which is manufacturing and sales agent for Solar's similar plant at Lima, at which a $2-million expansion program is underway.

Japan Synthetic Rubber Co., Ltd. has completed construction of a 25,000-ton-per-year dehydrogenation process unit to produce butadiene in Yokkaichi, Japan. Completed in less than two years, the new plant is designed to accommodate a

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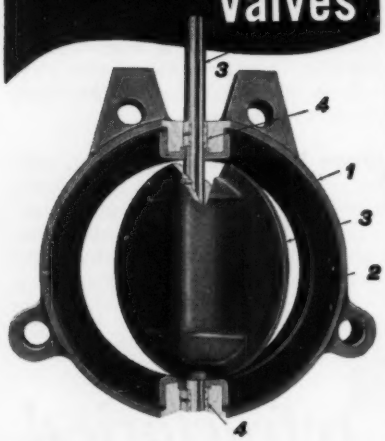

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wide variety of feed stocks ranging from straight-run butane to butane-butylene-butadiene combinations from steam cracking operations. A dehydrogenation catalyst is used with all feed stocks. The new unit is part of an integrated synthetic rubber plant at Yokkaichi. The plant's capacity will be 45,000 metric tons per year of SBR rubber. Houdry Process Corp. handled process engineering and has a crew of start-up operators on hand. Catalytic Construction Co. did basic mechanical engineering, and provided on-the-site consultation for Japanese contractors during actual construction.

DX Sunray Oil Co. has begun revamping and expanding the propane deasphalting unit at its Tulsa refinery. Cost of the work will be about $1 million. A new processing step is being added to the unit to produce an additional high-quality lube oil base stock. The system utilizes one of the latest developments in liquid extraction. Total capacity of the unit will be almost doubled. Foster Wheeler Corp., New York, is contractor for the project, which is to be completed by November.

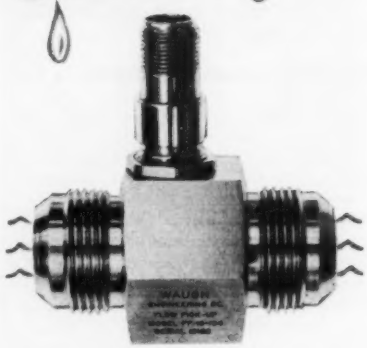
Tidewater Oil Co. has broken ground at South Norfolk, Va., for a new 102,000-barrel-capacity marine storage terminal. Construction of the new $750,000 facility, to consist of four large storage tanks, a modern administrative office, warehouse, truck-loading station, and a dock, was made necessary, the company said, by "Tidewater's expansion into Virginia and North Carolina markets." Design of the plant, scheduled to be completed in the fall, will permit later expansion to one million barrels of storage capacity.

Wilshire Oil Co. has completed construction of a new HF alylation unit with a capacity of 1,500 bpd of butylene alklate at its Santa Fe Springs, Calif., refinery. Fuel economy is effected by using exhaust steam to supply a substantial part of the process heat requirement of this plant in an iso stripper side-cut reboiler. Designed and licensed by Universal Oil Products Co., the unit was constructed by Wilshire forces in conjunction with C F Braun Co.

Tennessee Oil Refining Co., a division of Tennessee Gas Transmission Co., plans to construct a natural gas processing plant near Palacios, Texas. The 55-MMcf-per-day unit will be designed to extract 58,000 gallons a day of propane, butane and natural gasoline. To be located on a 30-acre tract two miles north of Palacios, the new plant will be built by O. L. Olsen Co. Completion is scheduled for the end of this year.

Foster Grant Co. has awarded to Scientific Design Co. a contract to engineer, design, and construct a polyethylene plant, the first in the United States to use the Agfo Process. Long range plans

18 million . . . 396 thousand gallons . . .



Waugh FF SERIES fluid bearing FLOW SENSOR

THE NEW STANDARD OF THE INDUSTRY

This **Waugh FF Series FLUID BEARING** flow sensor has been operating at close to maximum output **continuously** for a full year . . . and is still operating well within original accuracy tolerances. **18,396,000 gallons of water** have passed through it!

The **proven** service life of the **FF Series** sensor introduces a new standard of operation and a new degree of accuracy and reliability for precision measurement of cryogenics, jet-aircraft fuels, and many other difficult to handle fluids.

Available in a wide range of flow rates, it is the **only** sensor with no mechanical contact between the rotor and stationary elements. The turbine is supported by a filtered film of the fluid being measured adding to linearity and eliminating wear from either radial or thrust friction. The absence of conventional bearing surfaces results in reproducibility within 0.1% of flow rate, with linearity held to ±½%.

The outgrowth of many years experience in the design and production of flow instrumentation, the **FF Series** has almost universal application, and sets a new standard for the industry.

Request Bulletin 109 for complete technical data.

Waugh Engineering Representatives in Principal Cities

WAUGH ENGINEERING COMPANY
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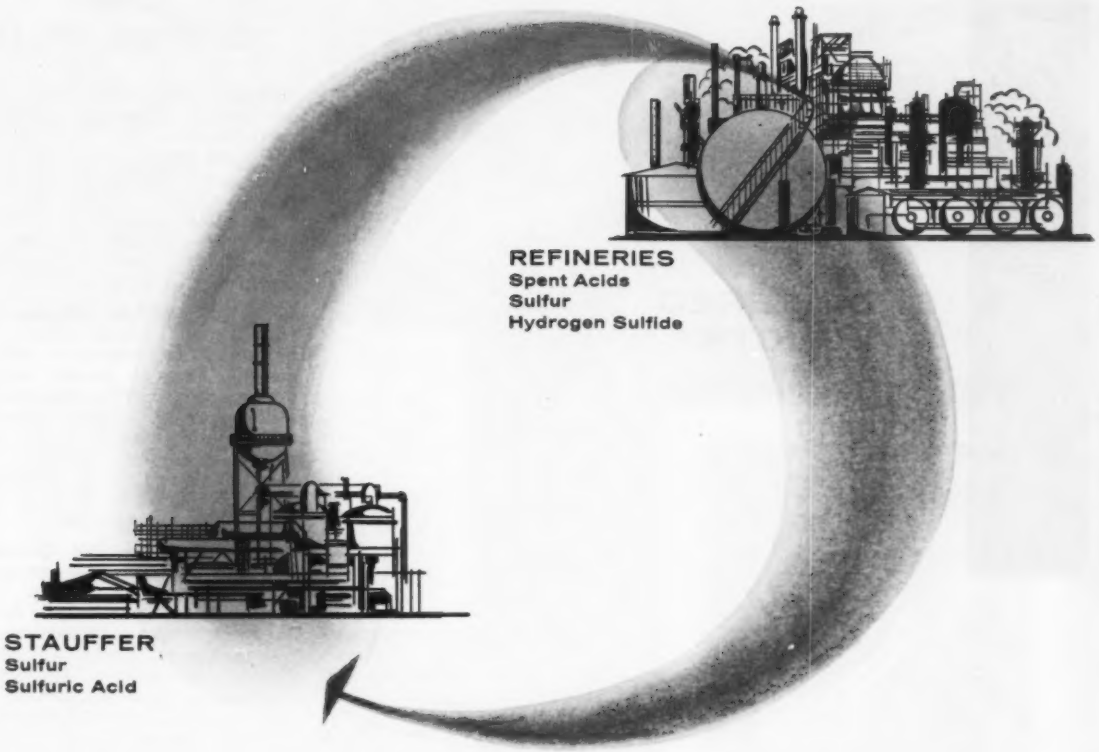

Stauffer is the Key to the Sulfuric Acid-Petroleum Cycle!

There is a steady flow of sulfuric acid in Stauffer's large fleet of carriers from our sulfuric acid plants to refineries throughout the country.

Similarly, there is a steady flow of raw and waste materials and sulfur by-products from refineries to our regeneration plants for conversion to water-white sulfuric acid of any specified concentration.

Stauffer's sulfuric acid regeneration plants are located in Texas, Louisiana, Indiana and California; in some cases adjacent to refineries for pipeline exchange of materials.

Rigid day-to-day traffic control of tank trucks, tank cars and barges assures scheduled deliveries.

Stauffer also supplies the petroleum industry with aluminum sulfate, caustic soda, muriatic acid, metal chloride catalysts, sulfur chlorides and numerous phosphorus compounds.

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75 YEARS OF SERVICE TO INDUSTRY AND AGRICULTURE 1885 1960

CONSOLIDATED CHEMICAL INDUSTRIES DIVISION, 6910 Fannin Street, Houston 25, Texas

For more data on advertised products, use Readers' Service Cards, last page.

ENGINEERED PRODUCTS

for Petroleum Refining

COMBAT CORROSION PROBLEMS

Garlock LATTICE-BRAID† Teflon Packings are perfect on pumps and engines in petrochemical, oil and gas service. They are strong, long-lasting, chemically inert. Withstand temperatures ranging from −120°F to +500°F. Less gland pressure is required to effect an adequate seal, resulting in longer sleeve and packing life, less downtime. Catalog AD-131.

Garlock CHEMISEAL† Mechanical Seals with Teflon* bellows possess greater immunity to corrosion than other designs. Easy to handle and install, do not score shafts, engineered to give a life expectancy many times that of other seals. Available in standard sizes to fit all pump shafts 7/8" to 2 1/16" shaft. Seals against all media in pressures to 100 psi at 75°C or 75 psi at 100°C. Catalog AD-164.

Garlock Teflon-jacketed Gaskets give you the advantage of using Teflon without sacrificing resiliency and deformability . . . particularly important on your glass-lined process equipment, standard metal flanges, and glass pipe flanges and fittings. Garlock offers four basic designs—slit envelope, milled envelope, formed shield, double jacket—and a wide selection of filler materials and thicknesses. Catalog AD-154.

Garlock GUARDIAN† Gaskets provide a safe, positive seal against high temperatures and pressures of steam, oils, gases, liquids. Gasket density, introduced during manufacture, assures dependable sealing under varying service conditions. Used at temperatures to 1050°F, pressures to 2500 psi . . . available in round, oval, square, flat side, diamond, pear and other shapes in practically any size. Large regional warehouse stocks are maintained at Camden, Cleveland, Houston and San Francisco. Catalog AD-104.

GARLOCK

For more complete information, call your Garlock representative at one of Garlock's 26 sales offices and warehouses throughout the U.S. and Canada. Or, write Garlock Inc., Palmyra, New York.

Canadian Div.: Garlock of Canada Ltd.

Plastics Div.: United States Gasket Company

Order from the Garlock 2,000 . . . two thousand different styles of Packings, Gaskets, Seals, Molded & Extruded Rubber, Plastic Products

†Registered Trademark
*DuPont Trademark for TFE Fluorocarbon Resin

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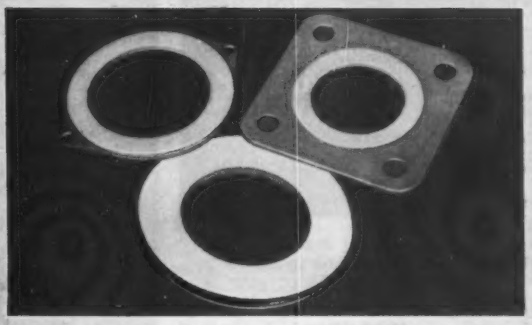
CHEMISEAL Mechanical Seals can be installed quickly and simply, offer leak-proof sealing without shaft wear . . . resist most reactive chemicals.

GUARDIAN Gasket V-shaped metal plies have an automatic spring action that reacts to variations in compression, internal pressures, and temperature changes. Assure leak-proof seal under most severe conditions.

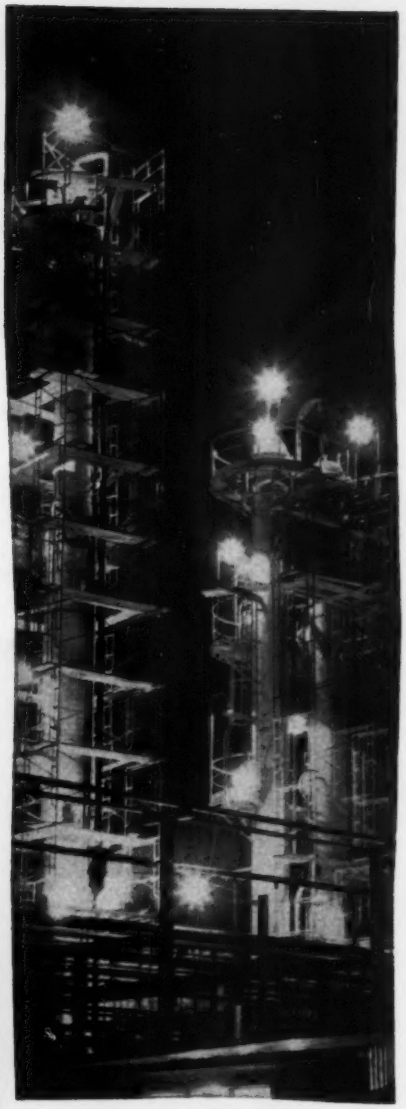
LATTICE-BRAID Teflon Packing lasts far beyond the limits of other packings . . . gives maximum service over wide range of temperatures, pressures. Only Garlock can give you Lattice-Braid.



Teflon-jacketed Gaskets offer the advantage of applying Teflon without the loss of resiliency . . . ideally suited to pipes, flanges in processing.

Drastic reduction
of heat loss with
PABCO
PRECISION-MOLDED
CALTEMP
a Calcium Silicate
Insulation

When vapors or liquids are conveyed or held at temperatures up to 1900° F.—when equipment is operated to high heat levels—Pabco insulations cut heat losses to absolute minimums. "Precision-Molded" by a patented process, Pabco's Caltemp and 85% Magnesia pipe and block insulations control temperatures within close tolerances. For data on technical advantages, case histories, or engineering consultation, write...or call a Pabco insulation engineer.



INSULATION GUIDE

Temperature	Recommended Pabco Insulation		
to 550°	85% Magnesia pipe covering	block	cement
to 1200°	Caltemp pipe covering	block	cement
to 1500°	Prasco 15 C pipe covering	block	cement
to 1900°	Prasco 19 C	block	

PABCO

INDUSTRIAL INSULATIONS DIVISION
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YOUR KEY TO MORE PROFIT

In the petroleum and petrochemical industries, new applications of cryogenics (low temperature separation) are opening the way to more profits.

Interested in low cost production of oxygen, nitrogen, argon, methane? purification or liquefaction of gases? Think *first* of Messer!

Write for *free illustrated brochure.*

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Building . . .

for the new plant include the polymerization and co-polymerization of propylene, butylene and other hydrocarbons.

The Agfo Process was developed by Imhico A. G., Switzerland, which is directed by Dr. Karl Heinz Imhausen. A large polyethylene plant utilizing the process and licensed directly by Imhico is under the construction in the USSR. Agfo process is a continuous, high-pressure polymerization technique for producing polyethylene. The process is highly instrumented, and by rigid control of polymerization, consistently reproducible products can be made over a broad range of density, melt index and other relevant properties.

Rhodiaceta Co., a subsidiary of Rhone-Poulenc, plans to build a hydrogen gas plant near Lyon in France. To be built by Chemical Construction, Ltd., the new unit will produce 2.5 MMcf per day of hydrogen gas by reforming Lacq natural gas. The resultant gas produced will be extremely pure containing less than five parts per million of carbon monoxide. Chemico will provide design, engineering and construction of the unit, which is scheduled to start operating early next year.

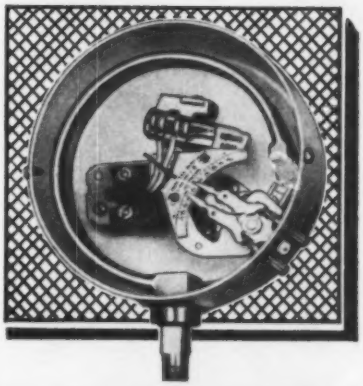
Electro-Chemical Co., Japan, plans to construct a petrochemical plant at Goi, near Tokyo. The $80-million facility will receive feedstock from Maruzen Oil Co. To be built over an eight-year period, with construction to begin in 1961, the complex will produce ethylene, polyethylene, chloroprene, ethylene glycol, ethylene oxide, acetaldehyde, vinyl acetate, acetic acid, caustic soda, methanol, toluene, styrene and phthalic anhydride.

Escambia Chemical Corp. has completed facilities involving a new process based on isobutylene oxidation to produce methacrylic acid and methacrylate esters. Under construction since last year, these facilities of semi-commercial size will soon have product available for development purposes. Plans are being developed for the large-scale plant, and various sites are being investigated.

Korean Petroleum Co., formed late in 1959 by local business interests, has succeeded in getting capital participation from a U. S. oil company to build a refinery. The government has approved construction of a 15,000-bpd plant to be built in one of four towns, Masan, Mokpo, Ulsan or Yosu. Completion of the $15-million project would be sometime in 1964.

Allied Chemical Corp. has started work on a major research expansion which will more than double the laboratory facilities of its General Chemical Division near Morristown, N.J. Construction is to be completed in the last quarter of 1961. With this additional space almost 500 research scientists and supporting staffs will eventually be accommodated. Stepped-up research on fluorine polymers,

A NEW ADDITION to MERCOID PRESSURE CONTROLS



316 STAINLESS STEEL

Welded Bourdon Tube and Pressure Connection

Series D-41, 243, 541

316 stainless steel welded Bourdon tube. ¼" (316) stainless steel pressure connection. Nickel plated mechanism. Outside adjustments. Calibrated dial. Hermetically sealed mercury contact.

Operating ranges: 30" vac.-75 psig; 10-100 psig; 30-400 psig; 75-800 psig. and 100-1000 psig.— with varying differentials and electrical capacity to meet your application.

Three case styles: General Purpose NEMA 1; Weather-Proof NEMA 1A, 2, 3, 4; Explosion-Proof Class 1 Group C, & D; Class 2 Group E, F, G, NEMA 7, 9, 9A.

WRITE FOR BULLETIN 619

THE MERCOID CORPORATION
4211 Belmont Ave., Chicago 41, Ill.

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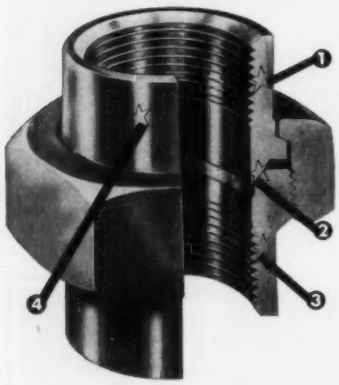
only
CATAWISSA
gives you all these features for your forged steel pipe union requirements



1. Uniform walls for even expansion and contraction under temperature changes. They follow the pipe!

2. Catawissa Ball-to-Angle Seats give you a "Perfect Seal" regardless of pipe alignment!

3. More than adequate wall thicknesses give you Catawissa's 3-to-1 Safety Factor (3000-lb. service, 9000-lb. test; 6000-lb. service, 18000-lb. test)!

4. Round, straight barrels for fast wrenching. No uneven or tapered surfaces to cause wrench slips or wrench locking!

Catawissa Perfect Seal Pipe Unions are made by Union Specialists from 80,000 lb. tensile strength steel (ASTM Spec. A-105-55T, Grade II). Steel forgings from our own forging mill are closely checked for imperfections . . . and finishing on modern, automatic machines with close inspection during and after production give you pipe unions second to none!

Write for Catalog 58 showing the complete Catawissa line of Perfect Seal Products.

for complete, guaranteed satisfaction

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CATAWISSA VALVE & FITTINGS CO.
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Building . . .

thermally stable fluids, and refractory metals, along with consolidation of technical services and petrochemical research groups dictates present expansion, Frank J. French, division president, said. Facilities for doing original investigations and pilot-plant operations are also being enlarged.

Conch International Methane Co. and a group of French firms have formed Cie. Algerienne du Methane Liduide (CAMEL) to build a liquefaction plant at Arzeu, Algeria, near Oran. The plant will get gas from the Hassi R'Mel field in the Sahara Desert. Liquid methane will be sold on a cash-and-carry basis. To be completed in 1963-64, the plant will process 48.5 MMcf of gas per day, to be increased later. Initial production of liquid methane will be 29.5 MMcf per year—to be doubled later.

Mobil Oil Co. will soon start construction of a delayed coking unit at its Beaumont, Texas, refinery. The unit will be one of the largest cokers started or completed by Mobil Oil during the past two years. Others are at Paulsboro, N. J., and Torrance, Calif. Size of the Beaumont investment was not disclosed. The unit will be completed in the spring 1961, and will convert 20,000 bpd of heavy oil into gasoline, light fuel oil, and petroleum gases.

Maruzen Oil Co. plans to team with Toyo Menka Kaisha, Ltd., a Mitsui trading company operating in Singapore, for construction of Japan's first foreign-based refinery. To be built in Singapore, the 20,000-bpd unit will be one of the first two in Singapore. Land for the $7-million plant will be leased from the Singapore government for 30 years. The unit is to be completed in November 1961.

Poland is said to be planning a capacity increase of its refinery at Czechowice, in Silesia. The unit's throughput will be upped eight-fold to 500,000 tons per year. Data and engineering information gained from this expansion is to be used in building the projected Plock refinery (see February 1960 issue, page 180).

Rhode Island Refining Corp. has withdrawn plans to build a planned 30-40,000-bpd refinery at Tiverton, R. I. The proposed $38-million unit will not be constructed as long as import controls are in effect, says the company. The firm added that "not enough crude is allowed into the country to justify a new refinery."

Colton Chemical Co. plans to expand its manufacturing facilities on the West Coast. A new resin plant will be built at City of Industry, Los Angeles County, Calif., on a five-acre tract. Supporting facilities will include a sales office, technical service laboratory, and a warehouse which will replace a bulk terminal being

"GREAT CARE MUST BE TAKEN IN SELECTING A GASOLINE ADDITIVE"

FMC offers Dependability, Manufacturing skill, Choice of products for Gasoline Additives

Dependability – FMC protects the refiner by producing ignition control additives from basic raw materials...assuring you of optimum quality control throughout the production process, and providing you with a dependable source of supply for these products.

Manufacturing skill–FMC has a reputation for technical know-how based on more than 25 years of experience in the production of organic phosphorus compounds.

Choice of products – FMC offers you several phosphorus compounds for consideration as combustion deposit modifiers . . . will soon be in a position to supply new compounds, enabling you to choose the additive best suited to your particular conditions.

If you need a phosphorus additive to eliminate engine knock, reduce surface ignition and spark plug fouling, you can rely on the experience and facilities of FMC. Write for more information about FMC gasoline additives. We will be glad to show how these products can meet your most exacting specifications.

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FOOD MACHINERY AND CHEMICAL CORPORATION
Chemicals & Plastics Division

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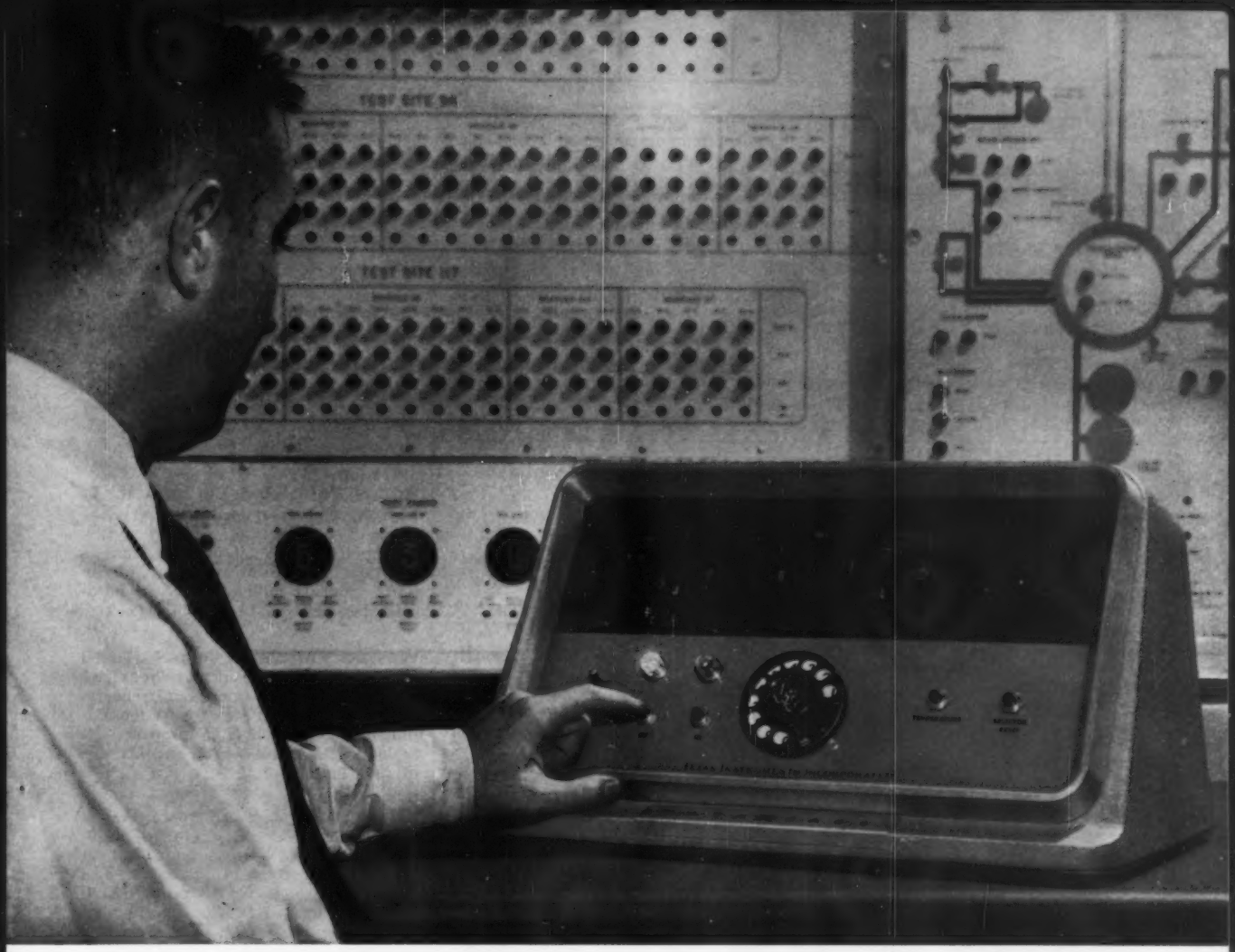

Use the only tank gauge system specifically designed for COMPLETE MEASUREMENT-ALARM-CONTROL

DATA-GAGE* system is the only field-proved tank gauge system that provides the multi-purpose functions of measurement, alarm and control without extra, expensive control and selector equipment. And, it is the only system that performs all these functions with the high degree of accuracy and reliability you require . . . check these outstanding features carefully:

Accuracy — DATA-GAGE system measures surface level to 1/16-inch accuracy in either stationary or floating roof tanks . . . is accepted for auditing purposes by major oil companies.

Reliability — DATA-GAGE *system cannot give false information!* All binary decimal code transmissions are automatically triple-checked before data is displayed. Float must break from the fluid surface to provide readout; point connections are verified from the field; polar code eliminates possible long-short ambiguity.

Versatility — *Same equipment* provides: digital and analog measurement including accumulator readout; control for motors, pumps, pilot valves, two- and three-position valves, adjustable chokes, controller set-points, etc.; alarm indication from any sensing contact. DATA-GAGE system can be provided with automatic programmers, data loggers, alarm and status displays.

Capacity — Up to 1000 tanks can be measured for liquid level and temperature with one standard system.

Economy — DATA-GAGE system has both low initial and long-range cost. No expensive extras are required. Code lines and power lines can be run in same conduit . . . often existing ground level gauge connections and pipes can be utilized. Transistors are used instead of short-lived vacuum tubes. Easy access plug-in units make this the easiest and safest to service of all systems.

For more detailed information on the DATA-GAGE system, request Bulletin No. M-601. If you have any problems in remote measurement and supervisory control, TI application engineers can help you.

TEXAS INSTRUMENTS
INCORPORATED
GEOSCIENCES & INSTRUMENTATION DIVISION
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*DATA-GAGE is a trademark of Texas Instruments. The system is licensed under Sun Oil Company patents.

Building . . .

operated at City Terrace in Los Angeles. The plant will be for resin polymerization.

Gewerkschaft Erdol-Raffinerie Emsland has completed construction of a 4,700-bpd combination Unifining-Platforming installation at Lingen, Germany. Currently producing a high-octane gasoline for blending purposes, the new Platformer processes a unified straight-run naphtha charge stock from Middle East crude oils.

Miranco Co., a recently formed independent refining company, is building a 500-bpd lube oil plant at Mendrisio, Switzerland. Currently under construction, the new $1.5-million plant is to be completed by the end of this year. It is being engineered by the Miranco staff.

Mitsui Chemical Corp. is considering construction of a fiber and resin plant (50 percent each) at its Otake plant near Hiroshima. The 19,000-ton-per-year, $9-million unit will employ the Montecatini process.

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TRINITY STEEL
You, whether designing
a simple steel tank or
complex pressure vessel, alw
have a "weather eye" open for
good, dependable fabrication
sources. Trinity Steel, Dallas, Texas
is a good fabricator. Further, Trinity
is a vigorous and young organization
looking for ways in which to serve you
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includes its pre
and past customers
Our modern shops have up-to-date equipment run by experienced men — and
in addition, we offer complete engineering facilities to supplement your
department's need. Code requirements? We meet all. Special steels?
We're experienced. Delivery? We keep our promises.
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7-3961 Dallas, Texas, for E. E. Garnsey, Bi
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Francesville, Indiana, and Mexico City.

Shell Chemical Co. may take over operation of American Cyanamid Co.'s Wallingsford, Conn., polystyrene plant. Capacity of the plant would be upped to 30-40 million pounds per year of general-purpose, high-impact material. Shell has been making semi-commercial quantities of polystyrene at Wallingsford for some time.

S.p.A. Celene, owned jointly by Societa Edison Co. and Union Carbide Corp., plans to build a propylene oxide and derivatives plant at Priolo, Sicily. Initial capacity will be 25 million pounds per year of propylene oxide. The Celene plant's polyethylene capacity is being expanded to 65 million pounds per year.

Ampol Petroleum Co. and H. C. Sleigh, Ltd. plan to team with California Texas Oil Co. to build a $29-million lubricating oil plant at Kurnell, Australia, near Sydney. Australia imports about 51 million gallons of lubricants per year.

Western Petroleum Corp. has added several new petrochemical processing plants to its Chanute, Kan., refinery. Included are a TCP wax treater for continuous wax bleaching, a propane, deasphalting unit and several vacuum distillation units.

Mobil Oil Co. and a group of operators are considering construction of a 30-MMcf-per-day gas processing plant in the Wimborne area of Alberta. The $3.75-million unit would produce 140 tons of sulfur and 100-bpd of stabilized gasoline.

Egypt has approved plans to build a fluid coking plant at Suez to produce middle distillates from about 32,500 bpd of residual fuel oil made from heavy Belayim crude oil. Egypt's Ministry of Industry is studying offers from U. S., West German, Italian and French firms.

American Cyanamid Co. plans construction of a 3,000-ton-per-year melamine plant at Gosport, England. To be located next to existing pharmaceuticals facilities the plant's output will be sold to the plastic laminates industry.

General Electric Co. has almost completed construction of its big polycarbonate plant near Mount Vernon, Ind. The commercial unit is a scale-up of pilot and semi-works plants at Pittsfield, Mass.

Pintsch Bamag, A.G. has completed two new plants at Rheden, West Germany, to dry natural gas by ethylene glycols. Each unit handles 5.3 MMcf of gas per day, and regenerates used glycol.

Esso Standard Oil Co. has completed installation of a light-ends unit at Linden, N. J. The new plant was constructed by Bechtel Corp.

For more data on advertised products, use Readers' Service Cards, last page.

COUNTRY-WIDE TESTS PROVE HOW TOTCO CONTINUOUS END-POINT ANALYZER CUTS CONTROL COSTS ...INCREASES YIELD

In major refineries from the East Coast to the West, the new Totco continuous End-Point Analyzer has demonstrated its ability to provide better control over product quality and yield. It quickly pays for itself and steps up profits. ■ This sensitive instrument continuously indicates the Engler End Point of a hydrocarbon stock or commodity in an operating range of 200° F. to 700° F. It delivers reproducibility within ±1°F., with results that correlate with ASTM D86 or ASTM D158. And its continuous analysis cuts the usual delays between quality change and compensating plant control... eliminates the time lag of batch analyzers or conventional laboratory tests. ■ Write or call today for further information. Request Bulletin 5900-11.

CASE HISTORY #1

Major Eastern Refinery

Use of the TOTCO End-Point Analyzer enabled this refiner to step up end-point specifications of reformer feed stock by 10°F with safety. Results: increased yield and a saving of over $200 a day. On the basis of this test, six additional Totco units were ordered!

CASE HISTORY #2

Major West Coast Refinery

Both TOTCO's End-Point Analyzer and Initial Boiling Point Analyzer were used here on a narrow-cut solvent. It was found that the analyzers kept yield on grade better than 99% of the time! Previous average with laboratory control was 90%.

CASE HISTORY #3

Major Mid-West Refinery

In this test, the TOTCO End-Point Analyzer was mounted in a trailer and used on a crude still to control first-cut products on stream. So successful was the test that the company ordered two additional Analyzers for use at other refineries.

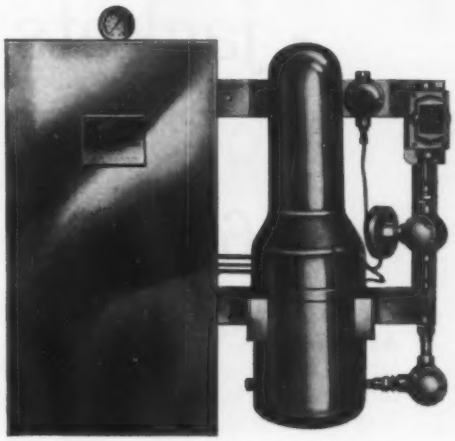
CASE HISTORY #4

Major Western Refinery

Demonstrating the versatility of the TOTCO End-Point Analyzer was this test where it was used to control the cut on heavy naptha. The test was a money-saving success, and the firm has since ordered additional units.

TOTCO CONTINUOUS INITIAL BOILING POINT ANALYZER

Totco also manufactures an Initial Boiling Point Analyzer. Write for Bulletin 1259-11 giving details and operating data.



TOTCO

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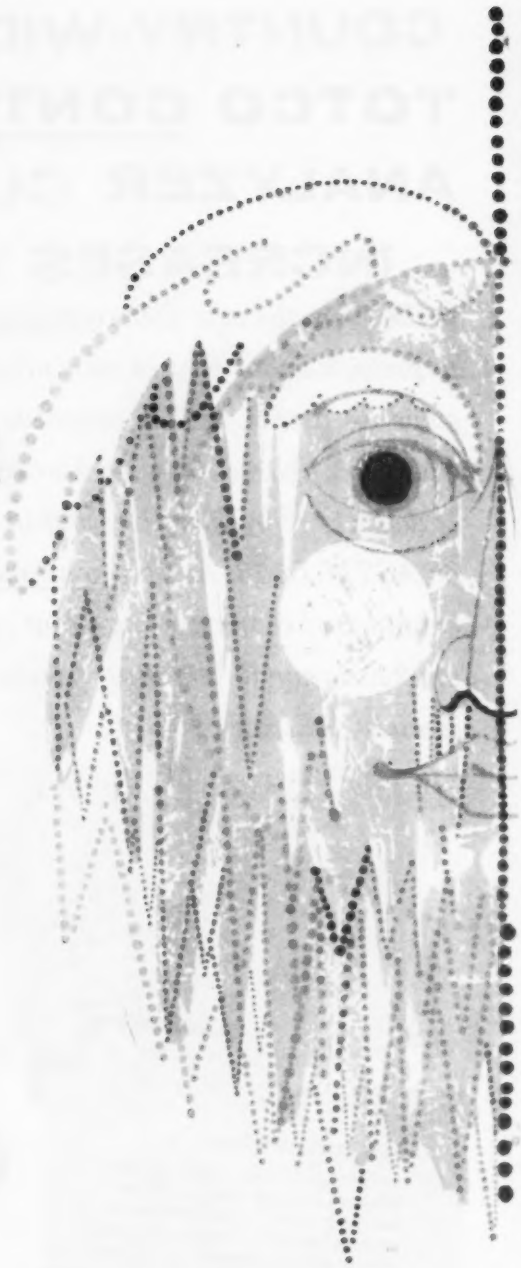
Manufacturers of Precision Instruments since 1929

You can meet any combination of temperature and weather with J-M

- cements
- jackets
- coatings
- fills



Along with the widest assortment of industrial insulations available, Johns-Manville offers a full line of cements, jacketing materials, coatings and fills. These important accessory items have been specially developed for use with J-M insulations to withstand both high process temperatures *and* exposures to all kinds of weather extremes on the job.

Don't settle for half a specification. Let your insulation contractor furnish the right combination of Johns-Manville materials vital to the satisfactory completion of any insulation job.

More than a century's experience in development and manufacture of top quality insulating materials insures the ability of Johns-Manville to meet *any* requirements and all extremes of temperature and weather. Talk over your specific needs with your J-M representative, or write Johns-Manville, Box 14, New York 16, N. Y. In Canada: Port Credit, Ontario.

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AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

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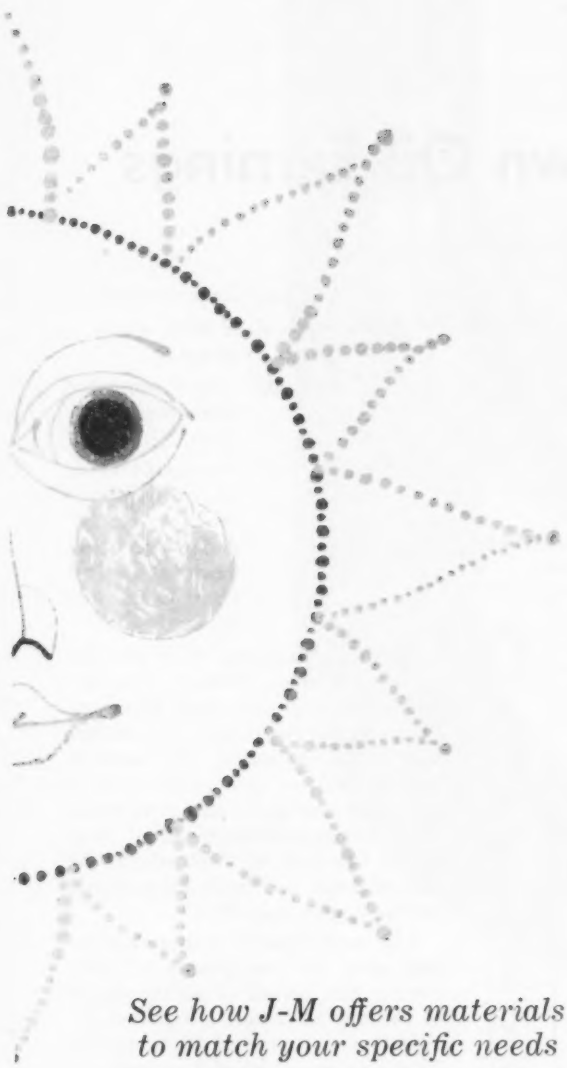


See how J-M offers materials to match your specific needs

J-M CEMENTS are designed for insulating or finishing applications. Eight types are made for general and special purpose use from such base materials as asbestos, magnesium carbonate, diatomaceous silica, mineral fiber, expanded vermiculite, hydraulic-setting cement, etc. Temperature limits range as high as 1900F.

J-M WEATHERPROOFING JACKETS for fire resistance and weatherproofing can be furnished factory-applied to pipe insulations, or separately for on-the-job installation, in a wide range of thicknesses and weights. Twelve different jackets to choose from—for temperatures to 250F.

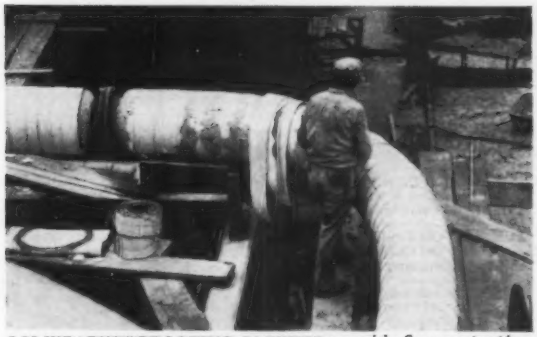
J-M INSULKOTE® weather-protective coatings guard insulation against corrosive atmospheres and extremes of weather. Insulkote can be troweled or gunned in place on vessels, tanks, piping and equipment. Available in six types, both "breathing" and "non-breathing."

J-M FILLS are recommended for insulating irregular spaces in high-temperature equipment.

Ask your J-M Insulation Contract Unit about these and the other quality insulating materials by Johns-Manville—your best assurances of long, trouble-free performance on the job.

JOHNS-MANVILLE INSULATING and finishing cements are applied over flat or irregular surfaces to give a smooth, crack-free finish that can easily be painted or given an additional weather-protective coating.

J-M INSULATING CEMENT can be applied by troweling in place . . . here, on a large cylindrical vessel previously covered with blanket insulation.



J-M WEATHERPROOFING JACKETS provide fire protection and weatherproofing as they meet any hot or cold insulating requirement. Most of the 12 available types are made of asbestos, felt-coated and saturated with asphalt.

J-M INSULKOTES can be ready-mixed and applied by trowel or spray gun over wire or Duramesh® fiber glass reinforcements. They effectively seal out moisture to prevent equipment corrosion . . . safeguard insulation investment.

For more data on advertised products, use Readers' Service Cards, last page.

What's Happening...

Troubles Still Hold Down Oil Earnings

THE PETROLEUM INDUSTRY in this second quarter of 1960 still is having difficulty in achieving satisfactory earnings. At the end of the quarter it will round out three full years of troubles that began at mid-year 1957, when the 1957-1958 business recession started.

Following is a summary of the trends of oil earnings in these past three troubled years:

1957: 2nd half—Earnings declined.

1958: 1st half—Lowest in recent years.

2nd half—Improvement.

1959: 1st half—Further sharp recovery.

2nd half—Down somewhat from previous year.

1960: 1st half—1st quarter same as in previous year.
2nd quarter about same as or less than in previous year.

Net Earnings of Some Oil Companies in First Quarter, 1960 and 1959

(All earnings per share are on basis of common shares outstanding March 31, 1960)

COMPANY	1st. Quarter 1960		1st. Quarter 1959		% Diff 1st. Q. 1960-1959
	$ Thousand	$ Per Share	$ Thousand	$ Per Share	
Amerada Petroleum Corporation	6,473	1.03	6,383	1.01	+ 1.4
Anderson-Prichard Oil Corporation	1,352	.75	1,347	.75	+ 0.4
Ashland Oil & Refining Company	3,409	.49	3,933	.57	— 13.3
Atlantic Refining Company	8,726	.93	12,346	1.33	— 29.3
Bishop Oil Company	28	.06	5	.01	+460.0
Champlin Oil & Refining Company	1,859	.43	2,224	.52	— 16.4
Cities Service Company	12,974	1.21	13,661	1.27	— 5.0
Clark Oil & Refining Corporation	15	.01	504	.33	— 97.0
Colorado Oil & Gas Corporation	d180	....	426	.09	.....
Continental Oil Company	15,280	.72	14,906	.71	+ 2.5
*Creole Petroleum Corporation	55,600	.72	68,408	.88	— 18.7
Crescent Petroleum Corporation	714	.34	686	.33	+ 4.1
Delhi-Taylor Oil Company	1,400	.27	2,509	.48	— 44.0
Gulf Oil Corporation	81,824	.82	66,673	.67	+ 22.7
*Imperial Oil, Limited	15,705	.50	13,560	.43	+ 15.8
*International Petroleum Company	9,500	.65	5,400	.37	+ 75.9
Louisiana Land & Exploration Company	5,604	.62	4,264	.48	+ 31.4
MacMillan Petroleum Corporation	54	.05	41	.04	+ 31.7
Maracaibo Oil Exploration Corporation	57	.12	66	.13	— 13.6
†Monterrey Oil Company	477	.24	603	.32	— 20.9
Ohio Oil Company	10,279	.74	10,198	.73	+ .08
Phillips Petroleum Company	25,804	.75	25,833	.75	— 0.1
Plymouth Oil Company	282	.11	1,527	.60	— 81.5
Pure Oil Company	5,766	.66	5,591	.64	+ 3.1
Quaker State Oil Refining Corporation	401	.49	448	.54	— 10.5
Richfield Oil Corporation	6,995	1.73	5,585	1.39	+ 25.2
Shell Oil Company	34,545	.57	34,467	.57	+ 0.2
Signal Oil & Gas Company	3,369	.35	4,329	.46	— 22.2
Sinclair Oil Corporation	12,308	.79	17,184	1.11	— 28.4
Sinclair Venezuela Oil Company	3,038	.76	3,895	.97	— 22.0
Skelly Oil Company	909	1.03	6,598	1.15	— 10.5
Socony-Mobil Oil Company, Incorporated	47,200	.97	45,200	.93	+ 4.4
Standard Oil Co. of California	60,728	.96	57,597	.91	+ 5.4
Standard Oil Company (Indiana)	31,689	.89	44,684	1.25	— 29.1
Standard Oil Company (Kentucky)	3,398	1.30	3,264	1.25	+ 4.1
Standard Oil Company (New Jersey)	170,000	.79	167,000	.77	+ 1.8
Standard Oil Company (Ohio)	5,066	1.01	5,096	1.02	— 0.6
Sun Oil Company	8,790	.71	11,227	.91	— 21.7
Sunray Mid-Continent Oil Company	9,440	.48	9,711	.57	— 2.8
Texaco, Incorporated	97,313	1.61	93,828	1.55	+ 3.7
Texaco Canada, Limited	3,474	1.06	2,634	.80	+ 31.9
Texas Pacific Coal & Oil Company	2,104	.54	2,020	.52	+ 4.2
Tidewater Oil Company	5,932	.38	10,463	.70	— 43.3
Union Oil Company of California	5,530	.65	4,890	.57	+ 13.1
Universal Consolidated Oil Company	676	.70	780	.81	— 13.3
Wilcox Oil Company	246	.78	216	.71	+ 13.9
*Total, 43 Companies	700,348	....	704,842	....	— 0.6

* Creole, Imperial and International are excluded from totals, being included as affiliates of Standard (N.J.).
† Data for quarter ended Feb. 29.
d Deficit.

Although earnings still are not quite satisfactory, there is some encouragement in the above summary. Of particular significance is the fact that in the first half of 1960 earnings will be about as good relatively as at any other time in the past three years. They will approximately equal those in the first half of 1959, which was the brightest and most encouraging half year since mid-1957.

The latest reported figures on earnings cover the first quarter of 1960. During that period 43 oil companies of virtually all categories reported aggregate net income of $700,348,000. That was only 6/10 of 1 percent less than the $704,842,000 that they earned in the initial quarter of 1959, when sharp recovery of earnings occurred.

In the present second quarter of 1960, there will be some difficulty in equaling relatively good year-ago earnings. Prices of petroleum products currently are lower than a year ago. But volumes of business will be somewhat larger, reflecting moderately increased demand. Also, oil companies have cut costs and curtailed expenditures, making possible relatively good reported net income.

Results Vary. While aggregate industry profits were virtually the same as last year in the first quarter, 21 companies showed increases and 21 reported decreases, while 1 had a

INTEGRAL FIN U-TUBES
for HEAT EXCHANGERS and REBOILERS

Now get steel integral fin or plain U-tubes on pallets from one source! Michigan Seamless has TAILORED TUBING, tailored to *your* specifications and ready for your heat exchanger. Buy TAILORED TUBING for minimum handling, minimum shipping cost, no scrap loss—deliveries on time! A variety of lengths, wall thicknesses and alloys, radii up to 24". Contact your Michigan Seamless representative. In the Southwest, call Gulf States Tube Corporation.

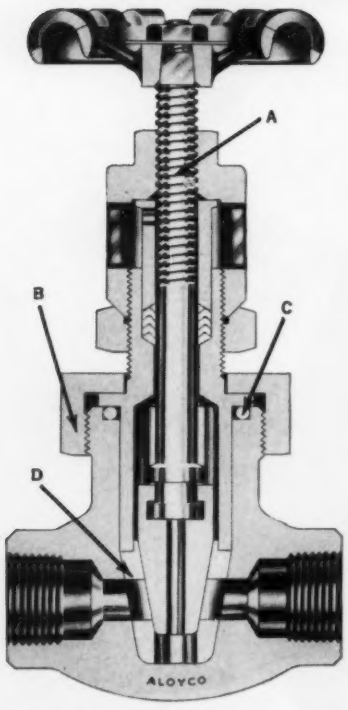
MECHANICAL, AIRCRAFT, PLAIN AND FINNED HEAT-EXCHANGER TUBING

MICHIGAN SEAMLESS TUBE COMPANY
SOUTH LYON, MICHIGAN

A SUBSIDIARY:

GULF STATES TUBE CORPORATION
ROSENBERG, TEXAS

Aloyco Plug Gate Valve #66 succeeds with severe corrosives for 10 straight years!



Shown ⅔ actual size of the half-inch valve

WHY? **A. OUTSIDE STEM THREADS** are away from corrosive area, prevent galling.
B. UNION BONNET provides extra strength and easy disassembly.
C. O-RING made of "Teflon"* provides tough, leak-proof seal.
D. SEATS made of "Teflon"* are pressure-tight, dependable, won't gall. Renewable.
STAINLESS STEEL: 18-8S, 18-8SMo, Aloyco 20.

FOR: Instrument lines, small lines handling viscous fluids, or where low pressure drop is important.

FACTS: full-floating plug disc exerts no twisting action on the removable seat in closing. Aloyco Stainless Steel #66 Plug Gate Valve: 1200 lb. at 150 F.; 600 lb. at 500 F. Sizes: ⅛", ¼", ⅜", ½". Want more? Write: Alloy Steel Products Company, 1303 West Elizabeth Ave., Linden, New Jersey. O-5

*Registered DuPont Trademark

Longer Lasting ALOYCO VALVES
1ST IN CORROSIVE SERVICE

ALLOY STEEL PRODUCTS COMPANY

Happenings . . .

deficit to compare with a profit. The fact that the industry's first quarter earnings equaled those last year was possible because of increases reported by all of the five large international companies: Gulf, Socony Mobil, Standard of California, Standard of New Jersey, and Texaco, Inc. They accounted for $457,065,000 or 65 percent of the 43-company total of $700,348,000 earned in this year's first quarter. That was for them an increase of $26.8 million or 6.2 percent over the $430,298,000 they earned in the first quarter of 1959. Gulf had the sharpest increase—$15.2 million or 15.2 percent, while the other internationals had modest gains of $2 to $3.5 million or 2 to 5 percent each.

Motor Oil-Gasoline Ratio Object of Study

A survey by API's Lubrication Committee has revealed that 91 percent of the industry has adopted the "Simplified Oil Drain Practice Recommendation" made by the committee in May 1959. It was recommended that engine oil be drained every 30 days in winter, every 60 days in summer, and that oil should never be used more than 2,000 miles. Of those surveyed, the remaining nine percent intend to adopt the committee's recommendation, and none will not adopt it.

The Problem. According to the API Motor Oil Study Panel, organized in 1958 to fight the continual decline in the motor oil-gasoline ratio, the crux of the problem was that:

- Car manufacturers were recommending longer and longer motor-oil drain periods, some running as high as 5,000 miles, while API was recommending 1,000-mile oil-drain intervals.
- Car dealers were improvising recommendations between these extremes.
- The public was confused, but it experimented with longer drain intervals and observed no dramatic change in engine performance.
- The service station operator drifted, tending to match his recommendation with what he judge to be the motorist's established practice.

In order to reduce confusion it was decided that the Crankcase Oil Drain Interval Recommendations adopted in 1952 should be up-dated and simplified.

Recommendation. In May 1959 the "Simplified Oil Drain Practice Recommendation was enacted. It was further recommended that three main avenues of attack be used on the remaining problems—"Operation Bootstrap," "An Approach to the Car Manufacturers" and "A Public Information Program."

Operation Bootstrap got started in December 1958. The Motor Oil Study Panel's Bulletin No. 1 was issued. Attached to it were several examples of promotional material being used by various companies in the interests of expanding sales of motor oil. To date, a total of 14 such bulletins have been issued, and the number of ideas disseminated is in the hundreds.

Approach to Detroit. The approach to Detroit had been going on for a long time, primarily at the technical level. It was felt that the time was ripe to change this approach to one at a higher, policy-making level, and several members of the General Committee who had been appointed as an Advisory Group to the Motor Oil Study Panel undertook this task.

Several contacts were made with car manufacturers and more will be made in the future.

While it is too early to assess results, it is encouraging that Chrysler Motors Corp. is stressing 2,000 miles as a drain interval. It can be hoped that the reasons which influenced them to change will influence others also.

Public Information Program. Although the General Committee of API's Division of Marketing approved spending $75,000 for a public information program, it was decided not to spend any money in a public direction until the Lubrication Committee was oriented.

As part of this orientation procedure, two surveys were conducted, one among car dealers and one among new car owners to learn their attitudes toward motor oil changes.

How Dealers Felt. Attitudes of the 2,000 car dealers interviewed follow:

- 80 percent state their oil change business is important to them:
  (a) Because of its dollar volume.
  (b) Because it increases traffic in their service departments.
  (c) Because it provides them with prospects for new car sales.
- 86 percent prefer a drain interval of 2,000 miles or less (the weighted average was 1,700 miles).
- The average oil drain recommendation made by dealers is 1,833 miles.
- Dealers state that car manufacturers' recommendations average 2,846 miles.
- 76 percent feel a uniform oil drain practice recommendation would be helpful.
- 79 percent recommend a chassis lubrication interval of 1,000 miles.

How Car Owners Felt. The attitudes of 1,500 owners of new Chevrolets, Fords and Plymouths surveyed can be summarized as follows:

- None said "Extended Oil Drain Interval" was a reason for purchasing a particular make of car.
- 42 percent observe an oil drain interval of 2,000 miles or less (the overall average was 1,700 miles).
- The average intervals for the new

Why Solar designs industrial gas turbines to weigh between 1 and 1½ lb/hp

by Paul A. Pitt
Chief Engineer
Solar Aircraft Company

The weight of Solar gas turbines is the result of a design philosophy that is unique in the small gas turbine field.

Most gas turbine designs fall into one of two extreme categories. Aircraft-type engines, at one extreme, embody highly sophisticated techniques for extreme light weight in relation to horsepower, but have resulting short life. The opposite philosophy employs the ultra-massiveness of steam turbines to assure long life.

There are important disadvantages in both approaches when long life, reasonable cost, dependable operation, simple maintenance and easy transportation and installation are required. While aircraft-design engines (of ¼ to ½ hp/lb) can be modified and derated for longer service life, the resulting product is inherently delicate. This compromise inevitably results in short life.

Paul A. Pitt

On the other hand, massive design (of 10 lb/hp and up) leads to unnecessary structural bulk and introduces problems of thermal lag and distortion.

Since World War II, Solar has designed and built a variety of gas turbine units with characteristics that lead to both long life and low weight. The Saturn gas turbine engine, for example, is an 1100 hp unit intended specifically for industrial and military installations. It has a weight-to-power ratio of 1.1 to 1.4 lb/hp.

Although it is designed for long life, it utilizes only enough materials in its components to satisfy structural and thermal requirements. This approach resulted in a design that makes no compromises with durability and performance, yet meets the needs of industry for flexibility in a small package. It has an 1100 hp rating at a specific fuel consumption of 0.61 lb/hp-hr and a continuous rating of 1020 hp at 0.63 lb/hp-hr SFC.

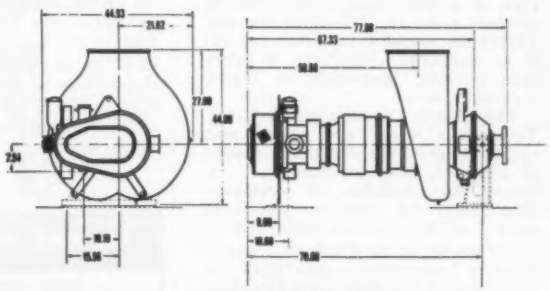
Meeting these objectives required an engine with a simple thermodynamic cycle and high efficiency components. An axial compressor was designed with an operating efficiency of 86%, and this was combined with a multi-stage, axial type turbine of advanced aerodynamic design. Over-all dimensions of the engine are shown in the figure below.

To fulfill workhorse service requirements, the engine was designed to operate at a conservative gas temperature of 1450 F continuous rating. The stress levels are also low, so that major rotating and stationary components will have more than 100,000 hours of life with long periods between overhaul. To keep costs down and assure dependability, the engine design is simple and straightforward.

In brief, the development program of the Saturn turbine adhered to three principles: Careful aerodynamic design for high performance; use of moderate temperatures and low stress levels for long life; and exhaustive component testing for ruggedness and reliability.

Presently scheduled field applications of the Saturn turbine include: Power source for 750 kw electric generator sets in process plants, portable field equipment, pipeline pumping, and gas compression in the petro-chemical industry. Other uses are as a power source for a 600 kw generator set in a commercial marine installation, propulsion units for marine and amphibious vehicles, and prime movers for off-highway vehicles.

Detailed data on Solar gas turbines and other turbomachinery is available. Write Dept. H-123, Solar Aircraft Company, San Diego 12, California.



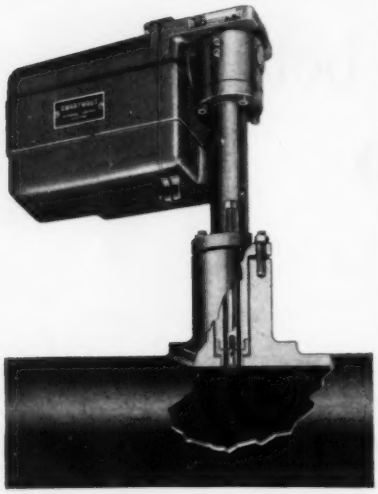
Saturn T-1000 dimensions

SOLAR
AIRCRAFT COMPANY

For more data on advertised products, use Readers' Service Cards, last page.

Great things are happening in AutroniC® Control

TOUGH PROBLEMS ARE NO PROBLEM



FOR THIS FOOLPROOF, FOUL-PROOF PRESSURE TRANSMITTER

Here is a primary sensing element for those tough jobs you'd like to forget. Mounted right on the process pipeline or tank, the Swartwout Flush Diaphragm Pressure Transmitter will effortlessly measure pressure or liquid level of polymers, slurries, asphalts, viscous fluids, molten metals and other difficult media. No stagnant pressure lines, no steam jacketing necessary . . . the stainless steel transmitter diaphragm fits flush with the inside of the vessel.

A friction-free linkage multiplies diaphragm motion and actuates the core of a differential transformer to produce a 0-0.5V AC signal for any Swartwout AutroniC indicator, recorder or controller. Sensitivity is better than 0.005%, reproducibility 0.1%, accuracy 1.0%.

The Flush Diaphragm Pressure Transmitter is just one unit in the constantly-growing AutroniC family of electronic instrumentation . . . a family that includes all necessary components for complete electronic control of any process parameter.

For details on the Flush Diaphragm Pressure Transmitter, request Bulletins A-713 and A-718. Swartwout Division, Crane Co., Hooksett Industrial Park, Manchester, N.H.

SWARTWOUT

. . . world leader in electronic process instrumentation

Happenings . . .

car are identical with the intervals for the old car—except for Ford:

	Chevrolet	Ford	Plymouth
Present Car	1,500	2,050	1,600
Previous Car	1,500	1,650	1,600

By fall 1959, it was decided to start the public information program. Selection of a public relations agency was followed by two months of intensive study of all the problems's phases, and in preparing a so-called "editorial brief." Collateral benefit has come from the planned public information program because more and more volunteer information has been appearing in the automotive press.

What the Press Said. *Automotive News* of April 25, 1960, stated. "Now that Chrysler Corp. has backed off its recommendations for 5,000-mile oil drain intervals, some other makers are expected to follow. Chrysler now says crankcase oil should be changed every 2,000 miles."

Motor Age of February 1960, stated: "Car companies doing an about-face in their recommendations on oil change intervals . . . Chrysler started trends . . . it now says crankcase oil should be changed every 2,000 miles . . . That's a switch from last year when it sanctioned 5,000 mile drain periods.

"In last couple of years, car companies have tended to lengthen oil change intervals . . . Most General Motors and Ford makes still recommend 4,000 miles, but they're now emphasizing time interval more than mileage interval . . . Oil companies say about 2,000 miles is right; or every 30 days in winter; every 60 days in summer."

Automotive News of April 18, 1960, stated: "I only wish that I was at liberty to tell you the whole story but it was given in confidence as the information is being held for a Society of Automotive Engineers paper which is supposed to get an airing next fall.

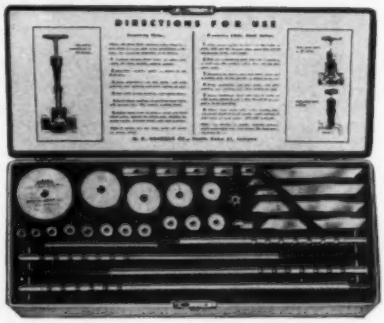
"But it was the concensus of the group that in the interest of longer engine life and less maintenance cost, the industry should not be advocating any more than 2,000 miles between oil changes for normal vehicle use and that oil filters should be changed with every second oil change."

Although it is too early to measure re-

use these
READERS' SERVICE CARDS* for more information

*** see inside back cover**

RESEATS VALVES and BIBBS QUICKLY ECONOMICALLY



Easily pays for itself on the first two jobs!

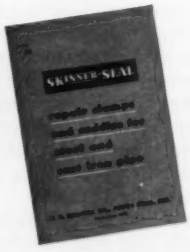
Reseats flat and tapered-seat globe or angle valves—all bibbs and faucets—in place, quickly and accurately. The saving, over tearing out and renewing leaky valves and fixtures, is tremendous.

Cutters operating under screw feed, leave worn, scored seats glass-smooth, level, absolutely accurate and tight.

A guide pilot centers each cutter; a tapered cone centers each spindle. Perfect alignment is inevitable. Cutters guaranteed. Write for literature!

2" for ¼" to 2" valves and ¼" to ¾" bibbs
List price $59.85

3" for ¼" to 3" valves and ¼" to ¾" bibbs
List price $79.50



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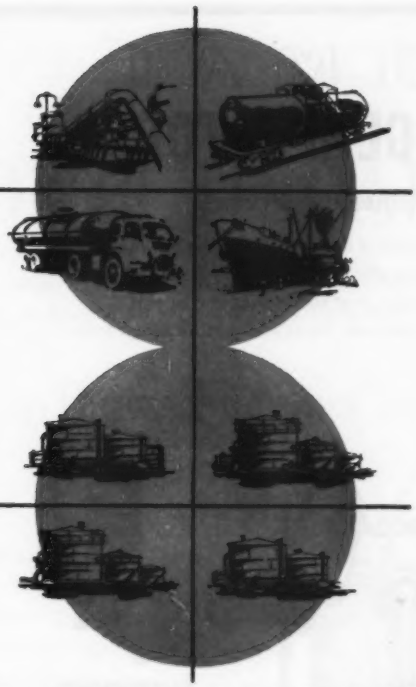

NALCO-TREATED FUEL OILS STAY FRESH!

Get rid of the hurry-up-and-sell pressure caused by unstable fuel oils that darken and sludge up when stored or shipped any distance. New Nalco 303-AC is the fuel oil dispersant-stabilizer that gives you *best* control of sludging tendencies—keeps fuel oils refinery-fresh, bright, and sludge-free even when shipped thousands of miles and stored for months.

Ask for product information on this new chemical for distillate fuels. It is available promptly from your Nalco Representative, or from Nalco direct.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY • 6259 West 66th Place, Chicago 38, Illinois

Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany
In Canada—Alchem Limited, Burlington, Ontario

Fuel oil at *left* is fresh from refinery, bright and clear. *Center*, Nalco-treated oil is bright and sludge-free after four months. *Right*, untreated sample in four months time has darkened considerably, already begun to sludge.

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PRODUCTS

SERVING THE PETROLEUM INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE

Nalco CHEMICALS

THERMAL
INERT GAS GENERATORS

Using the Sub-X Combustion Process

THERMAL utilizes unique principles of design to provide refineries, chemical processors, metallurgical plants, and other industrial users with a source of inert or purge gases that is compact in size and provides high outputs for low initial cost. Standard outputs range from 2,000 scfh to 60,000 scfh.

A 30,000 scfh Gas Fired Generator Ready for Use

SUBMERGED EXHAUST OF COMBUSTION PRODUCTS makes feasible the use of low-cost or contaminated water as coolant without concern over fouling of surfaces. The tank of water through which the gases pass provides an unusual degree of safety. Heat transfer efficiency is extremely high.

REFRACTORY IS ELIMINATED and maintenance costs reduced through the use of the high heat release THERMAL burner which can be fired with gas, distillate oil, or dual fuel. Units are supplied as a complete package and include all control and safety equipment.

For detailed information write for Bulletin #114-B

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Other Thermal Products & Services:

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Combustion & Heat Transfer Equipment

Happenings . . .

sults in any precise way, it is encouraging to note that many companies report an improvement in motor oil-gasoline ratios.

Indiana Standard Executive Comments on Import Control

Regulation of foreign oil imports is essential, but present federal control of imports creates discriminatory quotas that impose unjust hardships on some refiners. This appraisal of the year-old federal government program of mandatory curbs on foreign oil imports was reported recently to about 350 scientists, engineers, and technical representatives of Standard Oil Co. (Indiana) and its affiliated companies. William A. Kirkpatrick, manager of Standard's Crude Oil Coordination Department, Chicago, also said at the annual Joint Technical Meeting of the oil men that a "loosening of import control in the last half of the 1960's" seems a good possibility.

"A sudden end to controls might lead to chaotic conditions in the domestic industry," he observed. "Oil import controls are essential to the health of the domestic producing industry and the security of the nation. In a national emergency we cannot rely on overseas crude to supply our refineries. A domestic producing and oil transportation industry that had been severely crippled by a flood of foreign oil in peace time would be in poor condition to shoulder the tremendous burden of supplying wartime or other emergency petroleum needs. Discovery and development of oil fields is a long-term process that must be in continual action; it just cannot be started up at our convenience when disaster strikes."

Kirkpatrick's report showed that the government's program for curbing foreign oil gave some companies a great competitive advantage that can be detrimental to the entire producing industry.

Import allocations are based on two principles, Kirkpatrick explained. Some companies that historically have imported oil are allowed a percentage of their past imports as part of their quotas. Other companies receive their quotas based on past refinery runs, but these quotas are further limited by an inequitable sliding scale. This scale is determined on the principle that the larger a refiner's runs, the smaller should be his percentage share, he said.

When quotas are based on the historical record rule, the government insures that competition cannot invade the private domain granted to the few favored refiners, Kirkpatrick pointed out. "Thus the government preserves for them a position of great competitive advantage," he asserted.

"Use of the sliding scale prevents all refiners from enjoying equitable allocations," he said. "The sliding scale deliberately and systematically discriminates against large-scale refiners." Kirkpatrick

LGP-30 COMPUTER ABSTRACTS

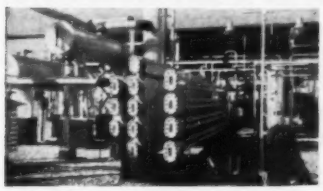
(Application Report #10, from which the following is abstracted, is free upon request from Royal McBee Corporation, Data Processing Division, Port Chester, N. Y.)

Subject: Design / User: Brown Fintube Company, Elyria, Ohio

The Problem: rush quotation for heat exchanger to potential customer. Determine best heat exchanger vs. cost combination. Perform necessary computations to obtain values for total surface area; total number of exchangers; area/exchanger; velocity and pressure drop – shell and tube; film coefficient; log mean temperature difference; overall transfer rate; clean rate; overall fouled rate; surface actually required; duty; price.

Method: the compact, low-cost Royal Precision LGP-30 Electronic Computer.

Input Data: except for special specifications which are handled by design engineers, non-technical personnel fill in data directly from customer inquiry sheets. This information is then punched on tape.



Solution: the engineer reads the above data into storage in specifically assigned memory locations on the computer's magnetic drum. The set of program instructions–also stored on the drum–then directs the computer where to find the input data and what mathematical operations to perform in the proper sequential order. The program then further directs the computer to store the various answers in specifically assigned memory locations.

Of notable interest is the incorporated test feature which allows any type and arrangement of sections to be tested by the computer. The program not only compares calculated values, but provides a corrective computation and recomputes all conditions until satisfactory values are obtained. The engineer need only type in the exact arrangement desired to have the computer calculate his proposed arrangement – assuring complete versatility and control over the program.

Output: all numbers required for the final specification sheet, including price, are provided – as well as key intermediate answers to enable the engineer to exercise judgment. The computer automatically controls the typewriter so that all answers are printed out in the desired format.

Conclusions: with the LGP-30, Brown Fintube has reduced total time on typical heat exchanger designs from one or two hours to approximately 3 minutes. Better design vs. cost combinations have been obtained–with a resulting increase in contract awards and the elimination of under-bidding. According to company officials, "perhaps the most significant contribution of the LGP-30 has been the release of engineering manpower for more basic and profound studies."

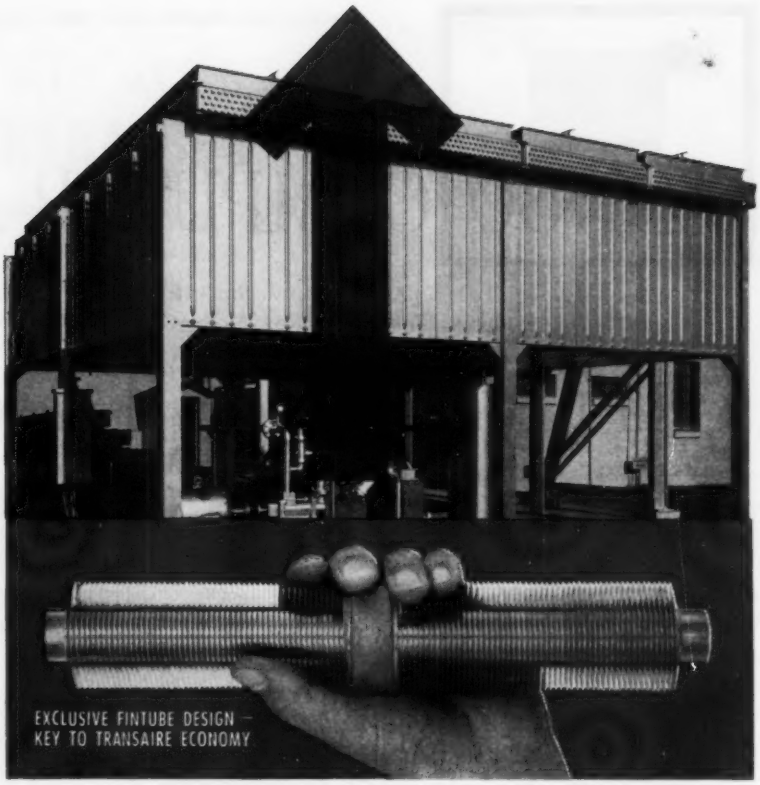
Royal Precision Corporation

Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. LGP-30 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing offices. For your free copy of Application Report #10, as well as full specifications on the compact, mobile LGP-30, write today to **ROYAL McBEE CORPORATION,** data processing division, Port Chester, N.Y.

For more data on advertised products, use Readers' Service Cards, last page.

WASTE HEAT LEAVES

...AT LOW OPERATING COST



Transaire Air-Cooled Heat Exchangers use free air for most economical heat dissipation

When waste heat is to be dissipated, Transaire Air-Cooled Heat Exchangers do the job efficiently and economically. Simple in design, Transaire units are now being used in many varied processing operations. Even in areas where water is unlimited, the cost of providing cooling towers, pumps, water treating, etc., makes the use of Transaire exchangers attractive.

Transaire exchangers are mechanically and structurally designed to give low maintenance and operating cost for extended periods of operation. High heat transfer efficiency is obtained by use of the Aimco fintube, an exclusive Yuba design with tapered spiral fins mechanically bonded so that the entire base tube is covered and protected against galvanic action. Fins are usually aluminum, although other materials are available for special requirements. Base tubing can be provided in practically any material, size or gauge desired. Fin spacing and height can be varied.

Next time specify economical Transaire, or if your present units are structurally sound, investigate modernizing through replacement with the new high efficiency Aimco fintubing.

Yuba also manufactures a complete line of shell and tube heat exchangers, and will recommend either type, whichever is required or best suited for the job.

YUBA

specialists in heat transfer equipment

YUBA-AIMCO DIVISION
801 West 21st Street, Tulsa, Oklahoma

YUBA CONSOLIDATED INDUSTRIES, INC.

Sales Offices in Atlanta • Buffalo • Chicago • Cleveland • Houston • Los Angeles • New York • Philadelphia • Pittsburgh • San Francisco • Seattle

For more data on advertised products, use Readers' Service Cards, last page.

said a great rise in imports probably would follow immediately if controls were lifted, and cutbacks in "already low levels of domestic production" would result.

Du Pont Sees 2nd Quarter Gain in Gasoline Demand

Total gasoline demand on U.S. refineries should run at 4.5 million bpd during the second quarter of this year, with production at a 4-million-bpd level, according to E. I. du Pont de Nemours & Co. Both figures show gains over the same period of 1959, the company pointed out. Demand forecast is 3.6 percent higher than for the second quarter last year, while total production is expected to be one percent higher than in 1959.

Bulk of the demand, as usual, is in the domestic motor gasoline area, with the second quarter forecast based on a daily forecast demand of 4.2 million bpd. That represents an increase of 4.1 percent over the same consumer market in the second quarter of 1959. About a quarter of this forecast gain is due to the abnormally low gasoline demand rate during May last year.

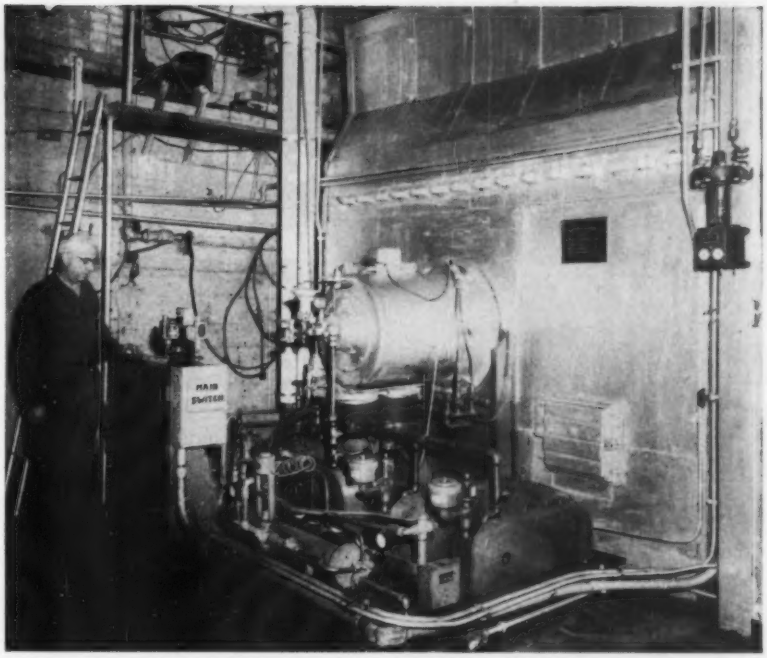
"Unless weather conditions dictate otherwise, domestic demand for motor gasoline should begin to produce consistent monthly gains over 1959," Du Pont's quarterly forecast noted. "A generally healthy economic climate is expected to stimulate driving, and there is still reason to believe that new cars added to the fleet should at least equal, if not exceed, the increase in 1959 over 1958, estimated at about 3.5 percent."

Domestic demand for aviation gasoline during the second quarter is estimated at 195,000 bpd, down 2,000 bpd from the 1959 rate. Export demands in the second quarter are forecast at 25,000 bpd of motor gasoline, compared with 22,000 bpd last year, and 30,000 bpd of aviation gasoline, down 33.3 percent from the second quarter of 1959.

Noting that production of gasoline during the second quarter of 1960 is forecast to show a one percent increase over the same period of 1959, the Du Pont report observed that "now that the peak season for all petroleum product demand has passed, refiners have an excellent opportunity to reduce operations and adjust long inventories." Total gasoline stocks at the end of the second quarter are forecast at 193 million barrels, 1.5 percent below the comparable period of 1959.

Motorists Are Seen Taking Better Care of Their Cars

"The American motorist now is paying more attention to the mechanical care of his car than at any other time in at least the last two decades. Recent consumer studies have shown a marked revival in the interest of the car owner in good



No Fuel Burning System Can Match O & S for Efficiency

Superiority of O&S burner systems can be demonstrated by these facts:

1. **Extraordinary Fuel Savings**—Impressive fuel savings are provided at *all* firing rates. Savings often pay for investment in a matter of months.
2. **Efficiency**—Higher *guaranteed* burner efficiency over a *wider* turndown rate than any other burner system.
3. **Performance**—O&S burner systems outperform all other assemblies. 5 to 1 turndown *without increase in excess air ratio is* widest in industry. Combustion air, accurately controlled, plays *no* part in atomization.
4. **Dependability**—No moving parts exposed to high temperatures. No tiny orifices to clog or distort.
5. **Flexibility**—Complete units for any commercial grade of fuel oil, any commercial gas (including sewer gas.) Air atomizing or steam atomizing.
6. **Typical Results**—A major New York State manufacturer is effecting a labor saving at the rate of $40,000 annually. (Name on request.)

Want more proof? We have an impressive array of case histories and performance data that are eye-openers. You owe it to yourself to investigate this outstanding burner system. Write for Bulletin 1255.

75th Anniversary

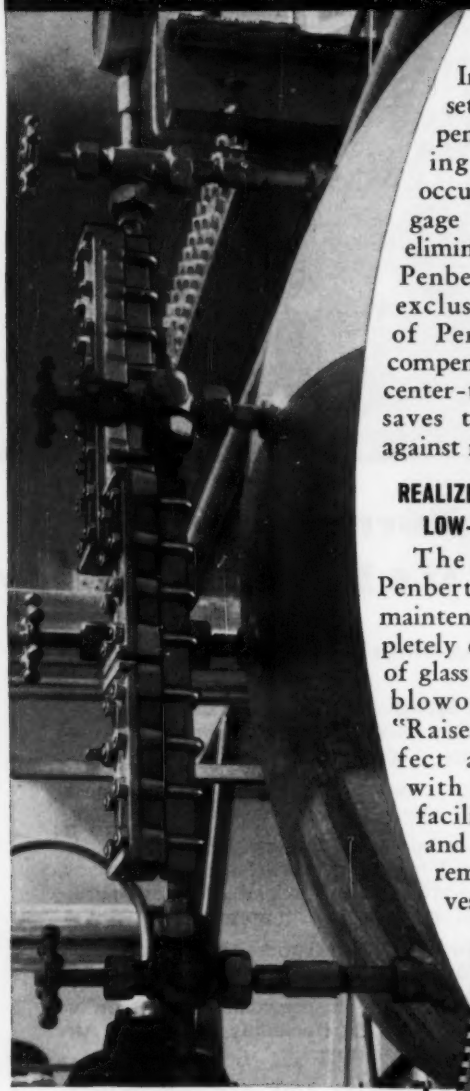
ORR & SEMBOWER, INC.

World Leader in Packaged Boilers and Burners

710 Morgantown Road, Reading, Pa. • Since 1885

For more data on advertised products, use Readers' Service Cards, last page.

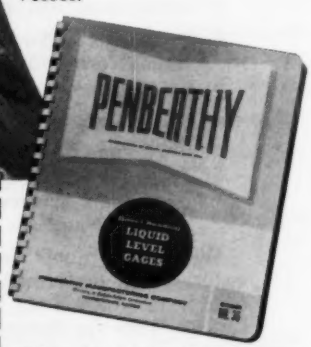
Save 50% or more
When you install PENBERTHY gage sets



Installing ordinary gage sets can be needlessly expensive and time consuming where inaccuracies occur in vessel tappings or gage assemblies. This is all eliminated when you mount Penberthy Gage Sets. The exclusive "Floating Shank" of Penberthy gage valves compensates for up to 3/8" center-to-center variation — saves time — and protects against mounting stresses.

REALIZE FURTHER SAVINGS IN LOW-COST MAINTENANCE

The unique design of Penberthy gages minimizes maintenance. The cover completely encloses sides and ends of glass and gasket to prevent blowouts. Full accessible "Raised Face" assures perfect alignment of frame with glass and gasket — facilitates cleaning, repair and maintenance without removing assembly from vessel.



Select the Right Gages for Your Requirements

REFLEX TYPE — 3 pressure groups to 3000 psig. Lengths to 12 ft.

TRANSPARENT TYPE — 4 pressure groups to 10,000 psig. Lengths to 12 ft.

SPECIAL SERVICE TYPES — High pressure, Frost-proof, Heating tube and Heating chamber, Welding pad, Large chamber and Inclined gages, Explosion-proof illuminator.

Write for Catalog 36. Illustrates complete line in detail including technical data, selection chart, specifications and properties, installation-maintenance instructions.

PENBERTHY MANUFACTURING COMPANY
Division of Buffalo-Eclipse Corporation
PROPHETSTOWN ILLINOIS

Happenings . . .

maintenance practices that will prevent breakdowns on the road and costly repairs." This was pointed out by Rudolph Cubicciotti, vice president of Sonneborn Chemical and Refining Corp., at a meeting of API's Lubrication Committee. He felt the renewed interest in car maintenance on the part of many owners was due to:

- A desire to avoid costly breakdowns, especially since disablement of a car on today's crowded highways often creates a safety hazard.
- Recognition that the automobile is no longer a luxury but a means of transportation essential to the owner's livelihood.
- A desire to obtain maximum performance at the least cost in miles-per-dollar.
- An increase in the number of drivers in the 18- to 25-year age bracket—most of whom have been exposed to good maintenance practices through driver education programs in secondary schools.
- Greater interest of many motorists in cars as a hobby—a result of the sports car upsurge in recent years. Sports car enthusiasts are, as a rule, more mechanically minded than the average autoist.

"However, in spite of a definite upturn in the interest of motorists in car care," Cubicciotti said, "many are confused when it comes to proper maintenance practices. Our studies show that motorists frequently ignore the advice of the car manufacturer, the fuel and lubricant supplier, and the service man."

One common point of confusion, he added, is the matter of oil-change intervals. Depth-interview studies conducted throughout the country revealed that there are nearly as many different intervals betwen oil changes as there were people polled on the question, Cubicciotti said.

Large Platinum Shortage Caused by Refining Method

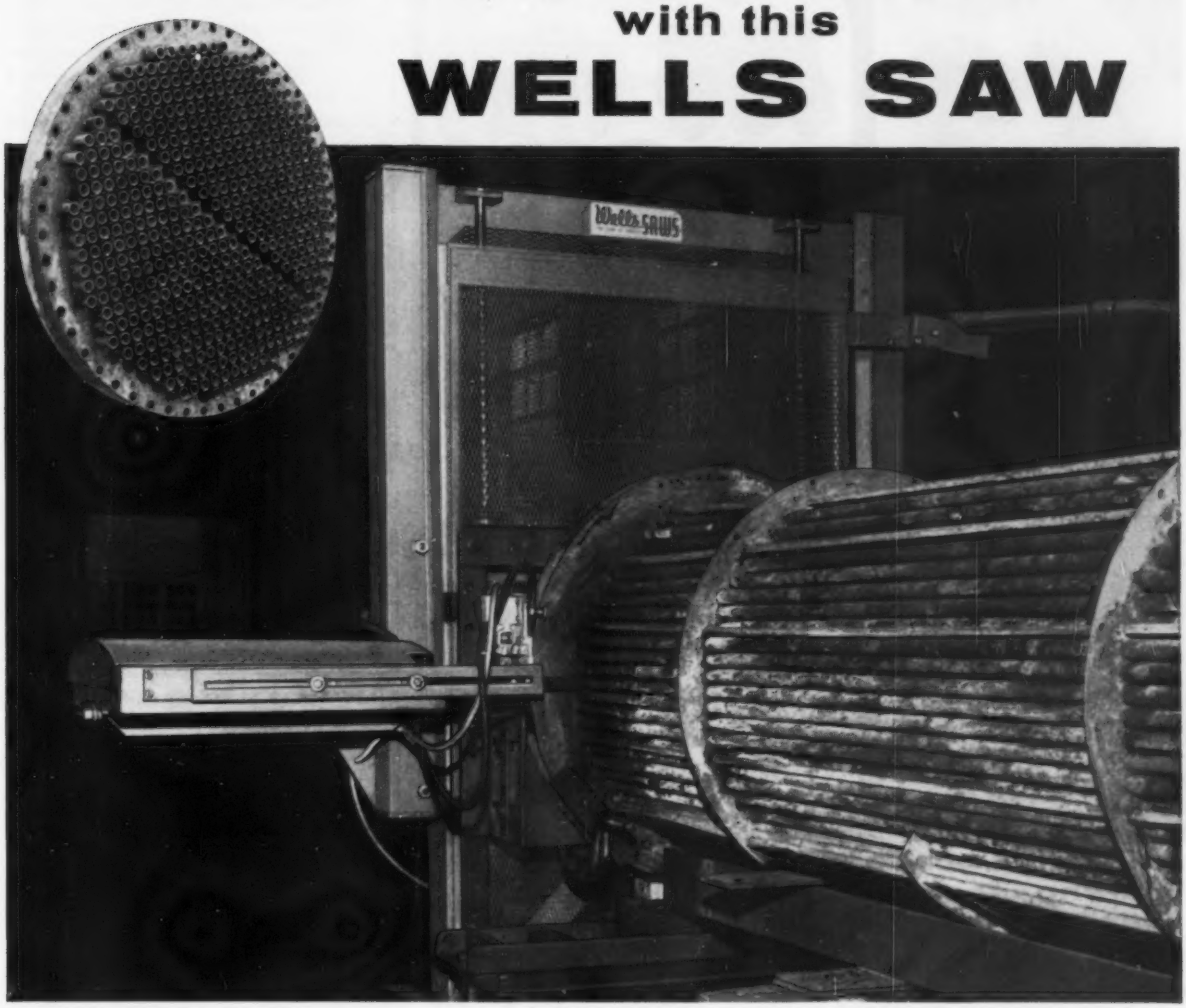
A worldwide shortage of platinum has been created by a new refining method for higher octane gasoline. "A sudden demand for platinum skyrocketed the price 50 percent to $118 an ounce when we were in the market for thousands of ounces," R. E. Bauman, Supplies Division purchasing agent for Standard Oil Co. (Indiana), said. This happened in 1955 and 1956, Bauman told scientists and engineers at the 18th Joint Technical Meeting of representatives from Standard and its affiliates.

"The platinum was needed as a catalyst for our new Ultraforming process to reform gasoline molecules and make higher octane gasoline more efficiently," he said.

In summer 1955 Standard and other major oil refiners suddenly stepped up use of the new processes using platinum. Platinum is mined mostly in South Africa with additional sources in Canada and Alaska in the free world. Sources also exist in Russia, which took advantage of

For more data on advertised products, use Readers' Service Cards, last page.

Cut Heat Exchanger Tube Bundles SAFELY . . . QUICKLY . . . CLEANLY . . . with this WELLS SAW



TYPICAL OPERATING DATA
(job illustrated above)

Type of Bundle	Debutanizer Condenser
Stationary Head	40½"
Sheet Floating Head	35-11/16"
Head Thickness	3¼"
Type of Material	Brass
Number of Tubes	480
Diameter of Tubes	1"
Gauge of Tubes	14
Type of Material	Copper Nickel
Size of Blades	21'0" x 1¼" x .042"
Teeth per Inch	8
Blade Speed	135 FPM
Cutting Time	165 Minutes

Write for Bulletin SM658 →

This is the Wells Model 12-20G-60 in action. Special Heavy-Duty Cut-Off Machines like this, developed by Wells Manufacturing Corporation, specifically for cutting tube bundles, are now doing the job efficiently in many oil refineries and chemical plants.

Model 12-20G makes safe and easy work of this difficult, hazardous, time consuming job, and materially reduces the cost of heat exchanger maintenance.

Standard models are available for cutting 48" or 60" diameter bundles. J.I.C. electrical standards and modifications of basic design are available to meet individual requirements.

If a safer, more practical, less costly method of cutting tube bundles is of interest to you, write for complete information.

Wells SAWS Wells®

The Pioneers of Horizontal
METAL CUTTING BAND SAWS
WELLS MANUFACTURING CORPORATION
880 Service Road — Three Rivers, Mich.

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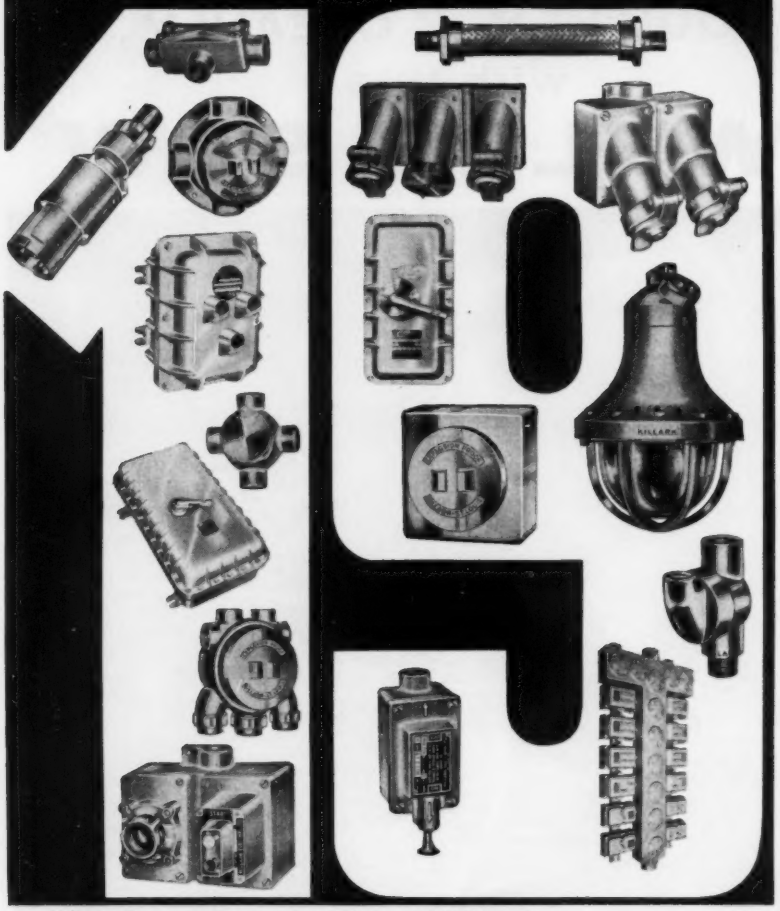
Fast Delivery On Explosion-Proof Equipment



...nineteen convenient Killark warehouses deliver explosion-proof fittings and fixtures promptly!

Regardless of where you are located in the United States or Canada, there's a Killark warehouse nearby with a complete line of aluminum explosion-proof electrical fittings and fixtures, U.L. or C.S.A. approved. Your Killark wholesaler probably has the item you need in stock or can get it for you quickly because his stock is backed up by nearby factory warehouse stocks in nineteen locations to assure you fast delivery.

Killark representatives & warehouse stocks

*Atlanta, Ga.
Ernest T. Loyd, Inc.
Baltimore, Md.
Eastern Sales Co.
*Boston, Mass.
Electrical Agencies, Inc.
*Buffalo, N. Y.
Eberhardt Electric Sales
*Chicago, Ill.
Jack L. Rowe & Son
*Cincinnati, Ohio
Arthur L. Ehlers Co.
*Cleveland, Ohio
Lusty-Thomson Co.
*Dallas, Tex.
Geo. E. Anderson Co.
*Denver, Colo.
Kenneth B. Schumann Co.
*Detroit, Mich.
Riecher Electric Sales Co.
Kansas City, Mo.
Wm. B. Terry Organization
*Los Angeles, Calif.
Kenneth Anderson Co.
Milwaukee, Wisc.
Martin-Goertner Sales, Inc.
Minneapolis, Minn.
Harry P. Smith Co.
New York City, N. Y.
W .J. Wickenheiser Co.
Omaha, Neb.
Walter C. McConkle
c/o Power Equipment Co.
*Philadelphia, Pa.
Harry G. Anschuetz Co.
*Phoenix, Ariz.
Kenneth Anderson Co.
Pittsburgh, Pa.
Crescent Sales Co., Inc.
Richmond, Va.
W. E. Sullivan, Jr.
*San Francisco, Calif.
F. M. Nicholas Co.
*Seattle, Wash.
Northwestern Agencies, Inc.
*Edmonton, Alberta
A. H. R. Louden Agency
Regina, Saskatchewan
Douglas G. Morton
c/o MacKay-Morton, Ltd.
*Toronto, Ontario
Killark Electric of Canada
*Vancouver, B. C.
Griffon Sales Ltd.
*Winnipeg, Manitoba
MacKay-Morton, Ltd.
Montreal, Quebec
Harry J. Issenman
Rothesay, N. B.
Lloyd G. Dykeman
*Warehouse Stocks

6008

Killark
ELECTRIC MANUFACTURING CO.
Vandeventer and Easton Aves. • St. Louis 13, Mo.
In Canada: Killark Electric of Canada, Ltd., 421 Islington Ave., South Toronto, Ontario

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the expanding platinum market, Bauman recalled.

Normally, mines in the Transvaal in South Africa supplied a little over 200,000 Troy ounces. Bauman said in a year, from 1955 into 1956, Indiana Standard and its affiliate, The American Oil Co., acquired 58,000 ounces alone for their units.

Russia had been dumping platinum on the market and then withdrew. The price had dropped to $77 an ounce in September 1955. Then the mad scramble set in and in four months the cost went to $118 an ounce. Both international major platinum suppliers were sold out for nine to 12-month periods, Bauman said. Later in 1956, the price began declining. Russia again entered the market, accentuating the decline, and withdrew as the price stabilized. Platinum now is worth about $80 an ounce.

Next Decade As Seen By Esso R&E Vice President

Chemical additives boosting octanes higher for all fuels were foreseen in the next ten years by Dr. W. J. Sweeney, vice president of Esso Research and Engineering Co., in a recent address to the Highway Transportation Congress. He said that increasingly purer compounds will be used to make gasolines for conventional automotive plants, making for clean and complete combustion. Sweeney foresaw the development of:

- Kerosine or diesel-fuel powered gas turbine engines for trucks, buses and off-the-road equipment.
- Clean and odorless diesel fuels.
- Stable automatic transmission fluids with better cold-flow properties, and with the load carrying ability of gear oils.
- Lower-cost automotive lubricants through improved additives and manufacturing methods.
- More resistant hypoid gear oils to permit smaller gears and differentials.
- Colored road surfaces made from thermoplastics mixed with sand or rock to denote speed zones and/or routes.
- Greases for permanent suspension and chassis lubrication at the factory.
- By mid-1960s, asphalt binders highly resistant to air oxidation and weather attacks. By early 1970s, asphalt pavements that will be all but indestructible.

3% Rise in Lubricant Demand is Forecast for '60

Indications are that domestic demand for lubricants in 1960 will rise three percent, the National Petroleum Association was told at its recent mid-year meeting.

J. A. Coble, of Socony Mobil Oil Co., said that there was no gain foreseen for exports, making the rise in total demand for 1960 average 2.3 percent. Estimated production capacity in 1960 is seen as just slightly higher than demand, Coble

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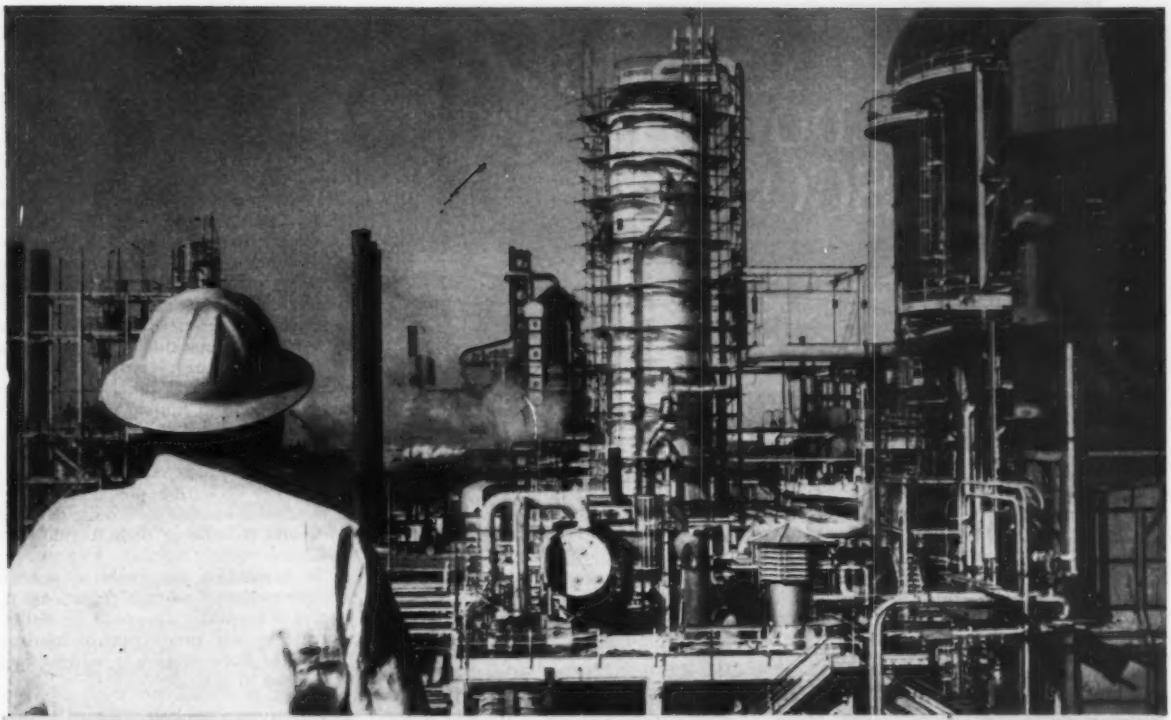

PROBLEM: An effective solid catalyst was sought for the alkylation of isobutane with ethylene to produce diisopropyl, a high octane gasoline component valuable for its high lead susceptibility and excellent volatility.

SOLUTION: Use of BF_3 with certain hydrated salts produces active alkylation catalysts which bypass many problems encountered with known catalysts. These new catalysts can be used at low temperatures—thus avoiding undesirable side reactions and mixing problems due to changes in viscosity.

NEED A BETTER CATALYST?

INVESTIGATE B&A® *BORON TRIFLUORIDE*

The versatility of boron trifluoride and its cost-cutting advantages make it a catalyst to be considered in almost any organic synthesis problem. The use of BF_3 as an alkylation catalyst in the preparation of diisopropyl (described above) is an excellent recent example. The next synthesis problem BF_3 will help solve may well be *yours!*

Here are some of the reactions catalyzed by BF_3: polymerization, alkylation, esterification, nitration, sulfonation, halogenation, isomerization, arylation, cyclization, hydration, acylation, and there are more!

Baker & Adamson has long been the leader in BF_3 research and production. We were the first to introduce boron fluoride etherate to industry. We pioneered in shipping the compressed gas by tube trailer transport—making it readily available in large commercial quantities. Steady, dependable supply is assured when you call on B&A for boron trifluoride.

Write today—for technical data on the properties and typical uses of B&A Boron Trifluoride gas or any of its complexes listed. Attach company letterhead, please.

- Boron Trifluoride, Di-acetic Acid Complex
- Boron Trifluoride, Di-n-Butyl Ether Complex
- Boron Trifluoride, Dihydrate (Stabilized)
- Boron Trifluoride, Ether Complex, Tech.
- Boron Trifluoride, Ethyl "Cellosolve" Complex
- Boron Trifluoride, Hexamethylene-tetramine Complex
- Boron Trifluoride, Monoethylamine Complex
- Boron Trifluoride, Monohydrate
- Boron Trifluoride, Para-cresol Complex
- Boron Trifluoride, Phenol Complex, Tech.
- Boron Trifluoride, Piperidine Complex
- Boron Trifluoride, Triethanolamine Complex
- Boron Trifluoride, Urea Complex

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Fine Chemicals

Allied Chemical

GENERAL CHEMICAL DIVISION
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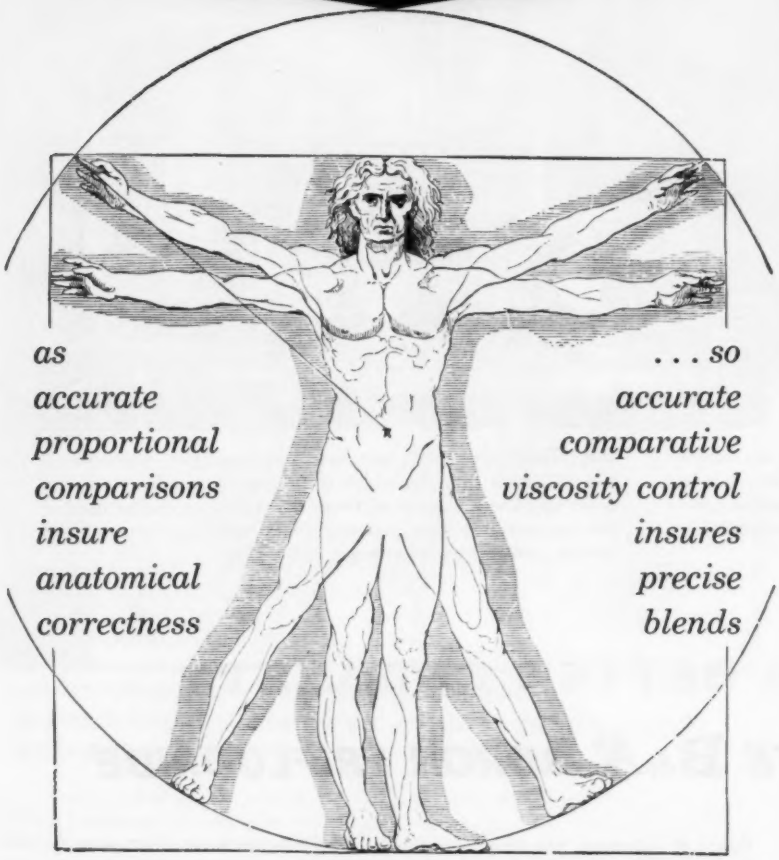
WHAT HAS THIS TO DO WITH VISCOSITY?



as accurate proportional comparisons insure anatomical correctness

. . . so accurate comparative viscosity control insures precise blends

and you can make them better with a

Bendix* Viscomparator

Accurate blending of petroleum products to a specification viscosity can be controlled continuously and automatically. The viscosity of the process fluid is compared with that of a reference sample at operating temperatures. Wide-range temperature compensation is inherent in the Bendix Viscomparator's design. Its sensing element withstands up to 650° F. (343° C.) and 1,000 psi.

For complete information about this surest, most modern method of controlling viscosity, write Dept. W-6.

*REG. U. S. PAT. OFF.

Cincinnati Division
3130 Wasson Road · Cincinnati, Ohio

THE Bendix CORPORATION

Export Sales and Service: Bendix International Division, 205 East 42nd Street, New York 17, New York
Canada: Computing Devices of Canada, Ltd., Box 508, Ottawa 4, Ontario

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said. The total increase in demand adds up to a little over one million barrels, he said.

Because estimated production capacity is almost 184,000 bpd, the unused capacity should average about 24-25,000 bpd or 13 percent, he said. Coble suggested that emphasis should be placed in the future, not on selling oil, but on selling lubrication as a form of insurance. "If we are to think of ourselves as providers of lubrication insurance rather than manufacturers of lube oil, we have to step up various things we are already doing," Coble said.

He said there was much research that could be done in finding new and better lubricants and in finding new markets. The oil business could give its customers more service and it could do a more effective job of letting people know it is in their own interest to use quality lubricants and to change them regularly, he said.

"In expanding our business, however, we must steer a careful course on supply," Coble said. "It would be folly to increase greatly production of lubricants just in the hope some way will be found to dispose of them."

February LPG Production Reported by Bureau Mines

The daily average production of natural gas liquids in February was six percent above February 1959, according to the Bureau of Mines, United States Department of the Interior. The daily average production of liquefied gases at refineries was eight million gallons, nine percent above a year ago. Ethane-ethylene production in February was 41 percent above February 1959.

The daily average demand for liquefied gases for fuel and chemical uses was 31 million gallons, 16 percent above a year ago. The daily average demand for natural gasoline in February was 11 million gallons, an increase of three percent above February 1959.

Stocks of liquefied gases including ethane totaled 666 million gallons, a decrease of 78 million gallons during February 1960. Underground stocks of liquefied gases totaled 449 million gallons, an increase of 173 million gallons from a year ago.

Time Off to Work In Politics Granted Conocoans

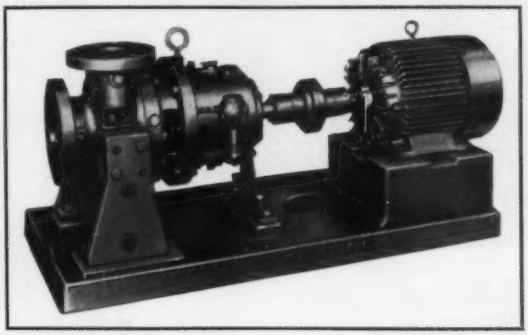
A policy granting employes time off from work without loss of pay to participate in political party activities has been initiated by Continental Oil Co. Continental is believed to be the first company in American industry to announce an official and written policy of this type.

The new policy applies to employes who have been elected and are serving as officers at the precinct level and above in the Democratic or Republican parties. It also applies to employes who have

THIS IS INTERMEDIATE-RANGE DESIGN

Robert Fornesi, Senior Application Engineer, Goulds Pumps, Inc.

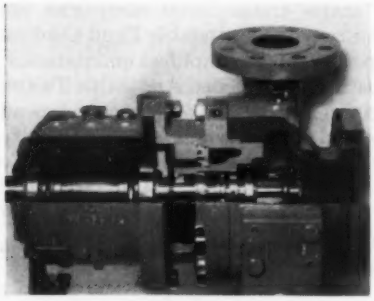
Changing requirements created this third dimension in process pump selection



Once upon a time you had to meet petroleum process applications with pumps in only these two ranges: (1) Light duty pumps to handle temperatures up to 200° or at most 300°. (2) Real heavy duty pumps for 200° to 800°. That's changed.

Here's why. Goulds product development group appraised the growing range requirements and services of petroleum process pumps. They found that 200° was no longer a realistic dividing line for process pump types. The need was for one pump which would handle all light duty applications and the growing number of intermediate applications as well.

Why should you have to buy a light duty pump with built-in temperature limitations when an intermediate-range pump could be built for almost the same price? Why should you pay for an 800° heavy duty pump to handle all the applications above 200° or 300°?



THIS DESIGN SOLVES HIGH TEMPERATURE SEAL PROBLEMS

Goulds designers felt they had the answer to both these questions in their plans for the Model 3775 line. This was not enough.

The design concept was verified by field research. The plans were rolled up from the drawing board and flown and shown all over the country. Plant superintendents and operating engineers saw them. They said yes.

They liked the rather obvious ideas that made INTERMEDIATE DESIGN POSSIBLE . . . the mechanical seal isolated in a seal chamber. This to allow for cooling of the liquid within the seal chamber. It made higher temperature handling with mechanical seals possible as it protected the seal. In similarly priced pumps the mechanical seal area behind the impeller is wide open. The hot pumpage is in constant contact with the seal. With the Model 3775 seals are not exposed to direct contact with hot pumpage. Cooler seals mean longer seal life.

COOLED CASING SUPPORT . . . A PLUS FEATURE

This was not enough. To be completely fit for INTERMEDIATE-RANGE (up to 650°) applications the Model 3775 had to have these features of costlier heavy duty pumps—cooled bearings and casing support.

Goulds Model 3775 has them all—water-cooled bearing housing and casing support as well as the seal chamber. This plus the choice of either internal or external flushing of the seal chamber. Single, double, balanced or unbalanced seals available to properly fit the application.

The pump is back pull-out type for easy maintenance. A spacer coupling allows you to remove the rotating parts without disturbing pipe connections or driver.

Built in accordance with API 610 specs, the fine mechanical features of this pump provide a husky line of pumps with maximum standardization and interchangeability of parts. Eleven sizes are built on the same bearing frame.

The Model 3775 is a horizontal center line mount with vertically split casings. Renewable casing wearing rings maintain proper clearance with impeller wearing rings. Leakage between suction and discharge chambers of the casing can be held to an absolute minimum.

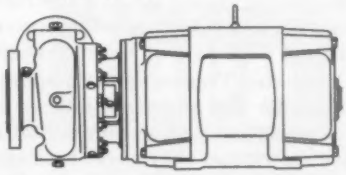
Talk over your process handling methods and problems with your Goulds engineer. He'll show you many more reasons why the INTERMEDIATE-RANGE 3775 is your best process pump choice for the majority of applications . . . *why it makes light duty pumps obsolete.* How it better fits the growing range of your process requirements.

AND AT LAST . . . A CLOSE-COUPLED PROCESS PUMP!

Goulds Model 3675 is the close-coupled version of the 3775. These units use the same liquid end as the frame mounts. The 3675 casing may be swiveled to four different discharge positions.

This integral pump-motor design provides the maximum in economy and compactness. Flexibility, too! One of our customers changed a process. A steel-case pump was required. Buy all new units? No, Goulds Model 3675 liquid ends fitted on the customer's present motors and provided the same rating. Only the casing was changed.

Get the complete story on these new pumps and all the others in the modern Goulds line. Send our factory the coupon below.



GOULDS PUMPS

GOULDS PUMPS, INC. Dept. PR-60, Seneca Falls, N.Y., U.S.A.

Send me a bulletin with complete application data on your INTERMEDIATE-RANGE DESIGN petroleum process pump.

Anything else? Please check.

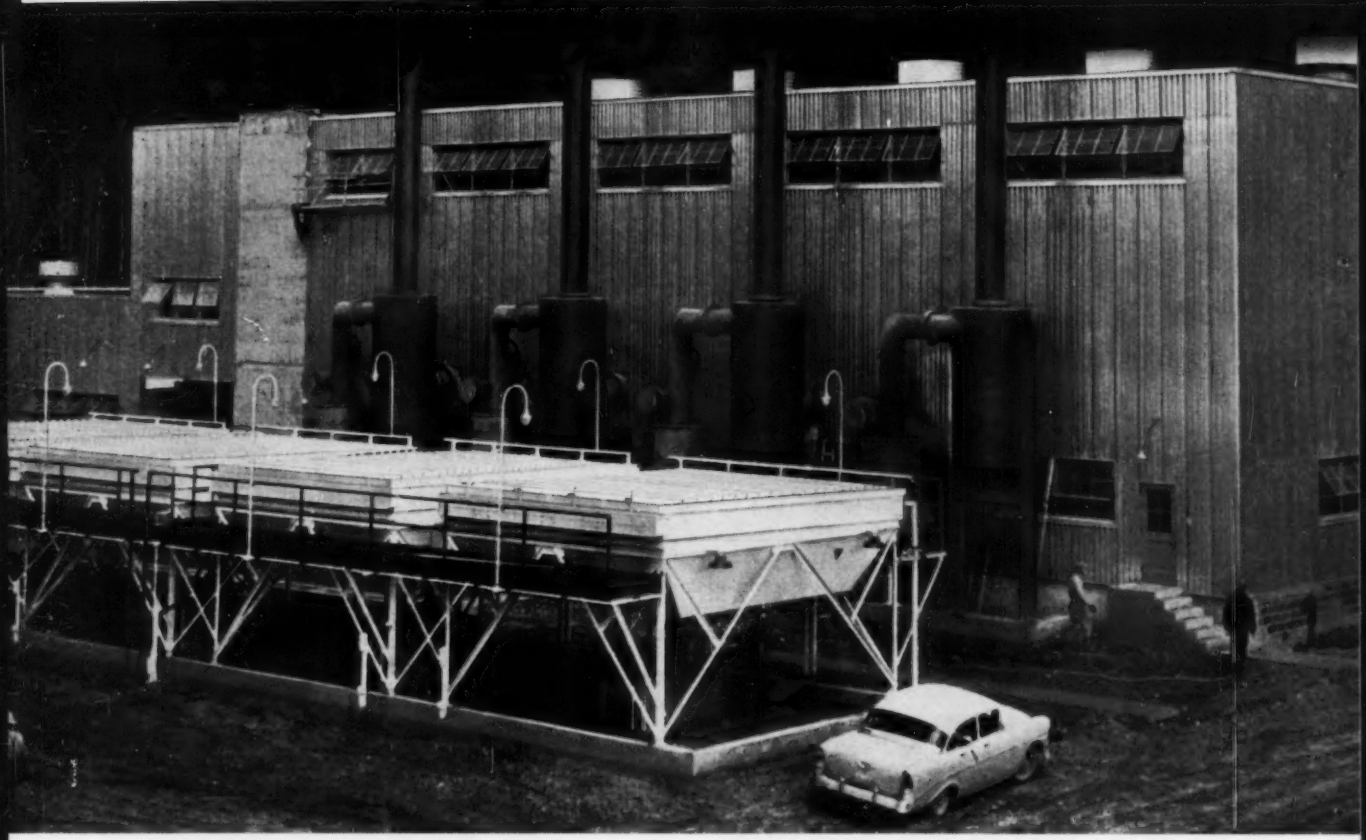
- ☐ 1-stage centrifugal—Model 3405
- ☐ 2-stage centrifugal—Model 3305
- ☐ Steel case Pumps Bulletin

NAME_____ DEPT. OR TITLE_____

COMPANY_____ ADDRESS_____

CITY_____ ZONE_____ STATE_____

For more data on advertised products, use Readers' Service Cards, last page.



Twenty air cooled units like this cool engine jacket water for four Canadian "Big Inch" compressor stations. Units are designed to dissipate 8.6 MBTU/hr. from the 288 gpm jacket cooling water at temperatures from 170 to 110° with an ambient temperature of 90° F. General contractor: Canadian Bechtel, Ltd.

Canadian "Big Inch" cools jacket water with Trane Fluid Coolers - at 35° below!

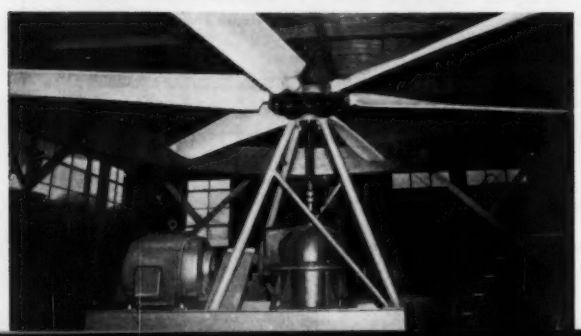
Westcoast Transmission Company's 650 mile-long, 30-inch pipeline system through British Columbia passes through country where winter temperatures are very low. Cooling engine jacket water for compressor stations along the way takes rugged equipment—coolers that can function efficiently at 35 or 40 degrees below zero.

Westcoast Transmission Company chose TRANE Fluid Coolers for this important job. Air cooling was essential at these extreme temperatures. And TRANE Fluid Coolers have shown that they meet exacting requirements under all weather conditions.

More and more major transmission companies are turning to TRANE for rugged, dependable Fluid Coolers. Many of these companies report simplified maintenance, a minimum of adjustment problems. And, with TRANE Fluid Coolers, engineers know that they can depend upon the accuracy and completeness of the capacity ratings—based upon the industry's most complete laboratory testing.

When you have a fluid cooling problem, turn to TRANE! Call your nearby TRANE Sales Office. Or write TRANE, La Crosse, Wisconsin.

The air handling segments have shutters for control of their forced vertical air flow, with variable-pitch propellers. (TRANE Fluid Coolers are also available with horizontal discharge.) 2-speed fan, motor and drive are factory-aligned on a single metal base. All framework parts are predrilled and match-marked.



For <u>any</u> air condition, turn to

TRANE

MANUFACTURING ENGINEERS OF AIR CONDITIONING, HEATING, VENTILATING AND HEAT TRANSFER EQUIPMENT

THE TRANE COMPANY, LA CROSSE, WIS. • SCRANTON MFG. DIV., SCRANTON, PA. CLARKSVILLE MFG. DIV., CLARKSVILLE, TENN. • TRANE COMPANY OF CANADA, LIMITED, TORONTO • 100 U.S. AND 19 CANADIAN OFFICES

been elected and desire to serve as delegates to any regular political convention of either party.

Time off not exceeding three days will be given a Conoco employe to attend a convention to which he is an elected delegate. Time off will also be granted an employe who is a party officer for the purpose of conducting election-day activities.

Changes in Import Program Are Announced by the OIA

Proposed changes in the mandatory import control program have been revealed by the Oil Import Administration. Change would:

- Reduce import allocations of "historical" importers by subtracting from their present allocations the average number of barrels per day of crude imported by overland means between Sept. 1, 1958 and March 10, 1959.
- Reduce ratios of imports-to-refinery inputs in Districts 1-4.
- Increase ratios of imports-to-refinery inputs in District 5.

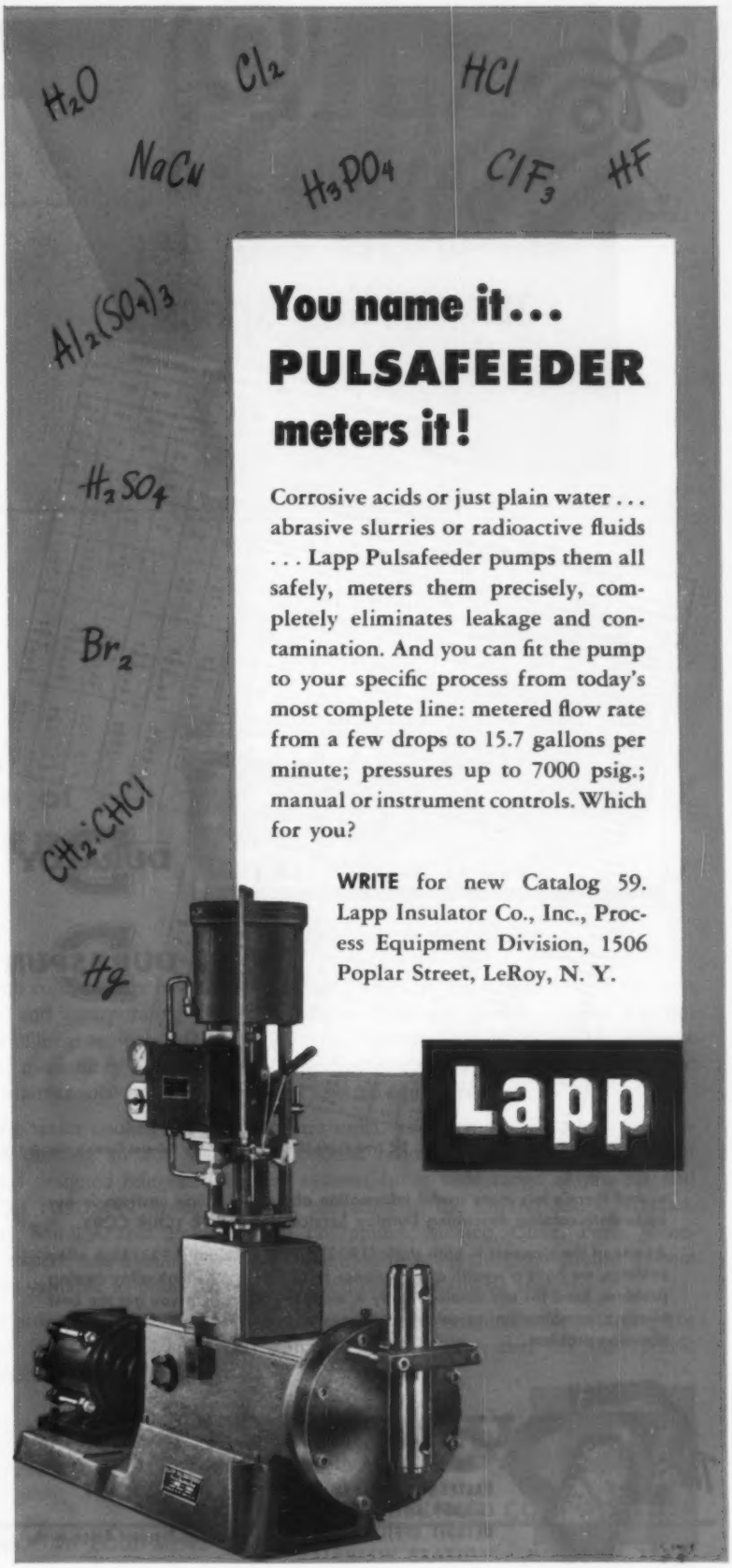
Crude, unfinished oil and products entering the United States by pipe line, rail or other means of overland transportation from the country where they are produced are exempt from restriction. Favorably situated companies can utilize this exemption to get imported oil. For purposes of computing allocations based on the last allocation under the import program, the latter will be reduced by the average barrel per day of such crude oils imported by overland means during the period Sept. 1, 1958-March 10, 1959.

Eye Irritant in Smog Revealed by Research Team

A major property in causing both eye irritation and plant damage has been isolated by a University of California research team. The substance is called peroxyacetyl nitrite. Previously, only acrolein and formaldehyde were thought to cause eye irritation. The researchers, in a report to API, said that the finding points up the importance of nitrogen oxides in smog and shows the need for their elimination in effective smog control.

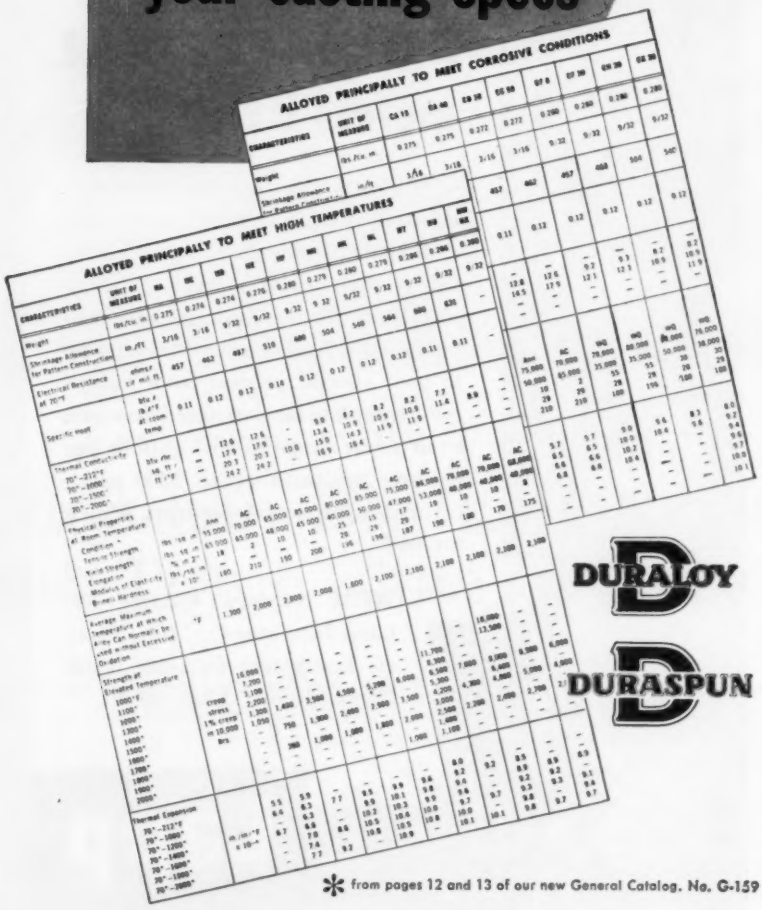
Urges Oil and Gas Groups To Push Public Relations

An appeal for oil and gas associations to set up a public relations plan that all in the industry "will proudly support and vigorously defend," has been made by W. G. Goldston, Houston, president of Mid-Continent Oil and Gas Association. He urged industry forces to join in such a plan before it is too late. Goldston and Alvin C. Hope, president


H_2O
Cl_2
HCl
NaCl
H_3PO_4
ClF_3
HF
$Al_2(SO_4)_3$
H_2SO_4
Br_2
$CH_2{:}CHCl$
Hg
You name it...
PULSAFEEDER
meters it!
Corrosive acids or just plain water . . . abrasive slurries or radioactive fluids . . . Lapp Pulsafeeder pumps them all safely, meters them precisely, completely eliminates leakage and contamination. And you can fit the pump to your specific process from today's most complete line: metered flow rate from a few drops to 15.7 gallons per minute; pressures up to 7000 psig.; manual or instrument controls. Which for you?
WRITE for new Catalog 59. Lapp Insulator Co., Inc., Process Equipment Division, 1506 Poplar Street, LeRoy, N. Y.
Lapp

For more data on advertised products, use Readers' Service Cards, last page.

TABLES
to help you select the proper alloy for your casting specs



✻ from pages 12 and 13 of our new General Catalog. No. G-159

DURALOY

DURASPUN

— and there's lots more useful information about high alloy castings in our up-to-date catalog describing Duraloy Service. SEND FOR YOUR COPY.

As one of the pioneers in both static (1922) and centrifugal (1931) high alloy castings, we have a wealth of experience to focus on your high alloy casting problem. Send for our catalog, study it, and then let us help you get the best alloying combination to solve your corrosion, high temperature and/or abrasion problem.

The DURALOY Company

OFFICE AND PLANT: Scottdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.

CHICAGO OFFICE: 332 South Michigan Avenue

DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

Happenings . . .

of IPAA, told the Texas Independent Producers and Royalty Owners Association that better inter-association relations were needed. "Oil men are inclined to make too much over the cry that the oil industry is a house divided," said Hope. Problems can be solved through "forums" of many associations. He added that he felt the industry is making progress in this direction.

Coal Makes Gains in Drive For Fuels Policy Study

Big gains have been made by coal interests in the campaign to get Congress to make a special study of the need for a national fuels policy. Chairman of the House Interior Committee, Representative Aspinall (D.-Colo.), has gone along with the proposal that a committee be established to look over the fuels situation.

The controversial proposition, though considerably amended from its original form, is opposed by most petroleum organizations. Oil and gas representatives feel the move will lead toward end-use controls on fuels. The House Rules Committee reportedly will soon give the proposal a hearing.

April-September Demand Is Forecast by the IPAA

Total demand during the heavy gasoline consuming season, April-September, will average 9.3 million bpd, an increase of 275,000 bpd—3 percent from the comparable period in 1959, according to an IPAA forecast. Gasoline demand is expected to average 4.5 million bpd during this same period. This is 113,000 bpd, or 2.6 percent higher than the comparable period in 1959. Domestic crude oil production should average about 6.8 million bpd between June and September. This compares with a current production of about 6.7 million bpd—about the same as in the like 1959 period.

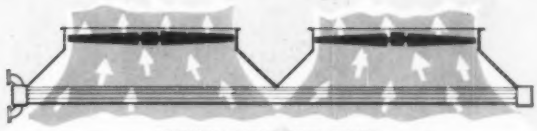
Enjay Merges With Humble As Chemical Marketer

The Enjay Co., Inc., petrochemicals firm, became the Enjay Chemical Co., a division of Humble Oil & Refining Co., on May 31. The firm will be directly responsible for both the marketing and the coordination of Humble's chemical products activities throughout the United States. In addition, Enjay will sell chemicals to Esso Export Corp. for distribution in foreign markets.

Enjay Division will have charge of and direct responsibility for all marketing of chemical products; coordination of supplies of chemical products; coordination of chemical research programs; and for recommending the location and nature of new chemical investments.

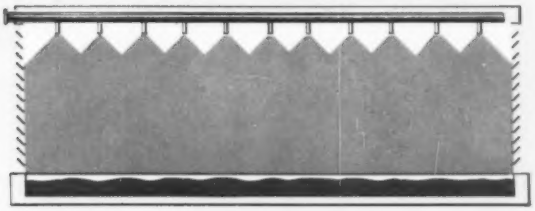
Should Process Plant Cooling Systems Use..

AIR ——



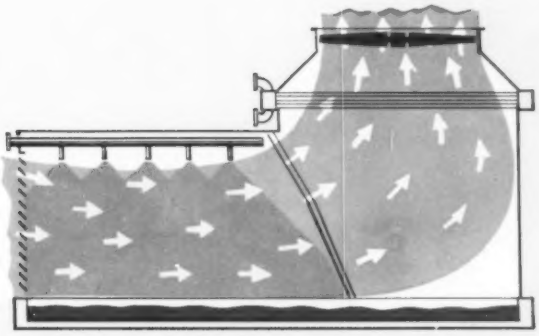
HUDSON SOLO-AIRE UNITS

WATER ——



HUDSON COOLING TOWERS

or a combination of
AIR AND WATER ——



HUDSON COMBIN-AIRE UNITS

The answer is found only through comparisons of economics of air, water or a combination of the two for cooling each process stream, and incorporating the results in one integrated cooling system. Factors to be considered include desired effluent temperature of each process stream; summer and winter ambient dry and wet bulb temperatures; availability and quality of water; possibility of public water pollution; space available; and first cost, maintenance cost, and operating cost of equipment.

HUDSON is unique in supplying water cooling towers, Solo-aire units, and Combin-aire units to comprise integrated cooling systems utilizing air and water in economic ratios. With the collaboration of owners' engineers, HUDSON has designed integrated cooling systems for a wide range of process and climatic conditions. Hundreds of HUDSON installations are operating in the United States, Ireland, England, France, Spain, Norway, Saudi Arabia, Pakistan, the Philippines, Mexico, Chile, Peru, Venezuela, and Canada. HUDSON experience, available without obligation in integrating the cooling system with process design, will be most valuable to plant owners if utilized during planning stages.

In early design stages of future projects let HUDSON collaborate with your engineers in selecting the integrated cooling system which best balances capital investment and operating cost for the specific process, climatic and water conditions.

HUDSON

ENGINEERING CORPORATION

ONLY HUDSON OFFERS ALL **3** *TYPES OF COOLING EQUIPMENT*

FAIRVIEW STATION • HOUSTON, TEXAS

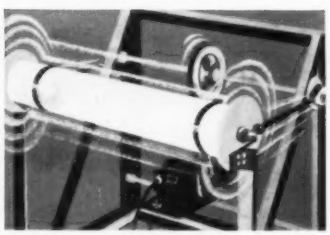
OFFICES: 16033 Ventura Blvd. Encino, California • 122 East 42nd St. New York 17, N. Y. • 199 Bay Street Toronto, Ontario, Canada • 17 Stratton St., Picadilly London W. 1, England • Corrientes 1115 Buenos Aires, Argen. • Rua Mexico 45 Rio de Janeiro, Brazil

TOUGH

NEW PIPE INSULATION

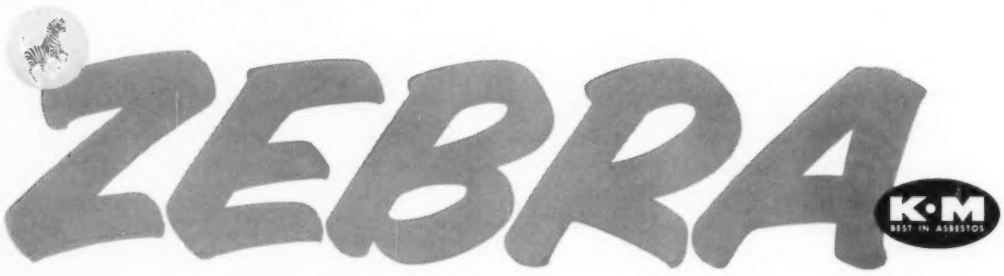
...deflection at breaking point 2 to 4 times that of ordinary insulation

You can almost forget about handling breakage with remarkable new "K&M" Zebra. As proved in tests by K&M and independent testing laboratories, Zebra won't crack or warp from shock or heat. It withstands intense vibration without cracking or abrading.



Zebra is made in half sections even for the larger pipe sizes . . . for faster application with fewer joints. Despite its rugged, full body, it's relatively lightweight . . . easy to cut and fabricate. It's a low, medium and high-temperature multi-layer sectional-type thermal insulation. And it meets your requirements for density, conductivity, modulus of rupture, and resistance to soaking heat. Write today for more information and a free sample of new "K&M" Zebra. It's tough, economical, fast to apply. That's Zebra . . . by K&M! Keasbey & Mattison Company, Ambler, Pa. Dept. I-260.

• for temperatures of 200°F to 1200°F • smooth surface won't irritate or cut skin • made of calcium silicate-asbestos fiber bonded felts • can be re-used . . . dismantled and re-applied • practically dust-free • available in a wide range of sizes and thicknesses.



KEASBEY & MATTISON at Ambler

Happenings . . .

Towering 17 stories above the Southern California terrain is this gas holder, built to serve the Long Beach Gas Department. The tank, said to be the "world's largest," drawfs its operating plant. It will store 5 MMcf of natural gas during off-peak hours.

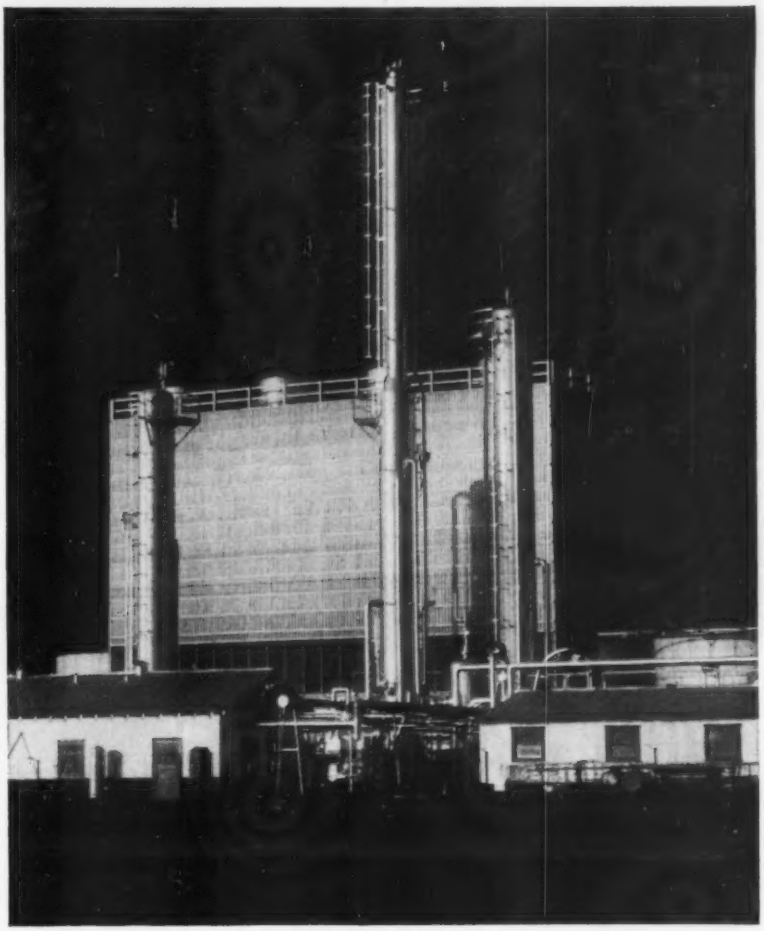
Mayor L. L. Briggs, South Norfolk, Va., maneuvers the controls of a huge bulldozer to break ground for the newest industrial addition to his community, Tidewater Oil Co.'s 102,000-barrel-capacity marine storage terminal, scheduled to be completed in the fall.

A new "world safety record" for petroleum refineries has been set by employes

new from Calgon . . .

HAGACIDES

a complete line of high toxicity biocides



Designed specifically for cooling water treatment, Hagacides provide a complete line of biocides that are highly effective. They may be used either by themselves, or as a supplement to other types of treatment.

Hagacides are effective against algae, slime, iron and sulphate reducing bacteria, and the complete spectrum of biological agents that impede cooling water operations. Hagacides are compatible with other water treatment chemicals; they are stable and are highly resistant to temperature extremes.

Easy to handle and feed, all Hagacides are completely safe for cooling tower wood. They are non-volatile, non-oxidizing and contain no corrosive metals. They penetrate and loosen debris which harbors microorganisms, and adhere to surfaces for a long lasting kill.

Hagacide biocides have proven themselves effective in situations where other biocides have failed. For more information, write:

CALGON COMPANY

HAGAN CENTER, PITTSBURGH 30, PA.

DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.

For more data on advertised products, use Readers' Service Cards, last page.

Pencil test demonstrates how the DURABLA valve member tilts and opens easily, without noticeable friction. Compare this with any other pump valve.

NO. 1 REASON

this is the ideal valve for high-speed pumps

Key to the high efficiency and free action of a DURABLA V-7* Pump Valve Unit is the patented lightweight valve member. Making only "point contact" on the sleeve, it can't bind or hang up. Nor can it warp, thanks to its unique arched design.

This low-lift valve member is designed to open with a tilt, following the flow lines. Valve action is very sharp, thanks to lightness and flexibility. That's why DURABLA is the only valve ideally suited to high-speed operation.

DURABLA valve units operate freely under temperature-pressure extremes, with corrosive fluids and in any position. Available in 17 sizes, they will meet over 300 variations in installation requirements.

Send for booklet PE 60.

DURABLA MANUFACTURING COMPANY
114 Liberty Street, New York 6, N. Y.

DM-35

*Patent applied for

DURABLA®

Manufacturers of DURABLA sheet packing, gaskets and check valves

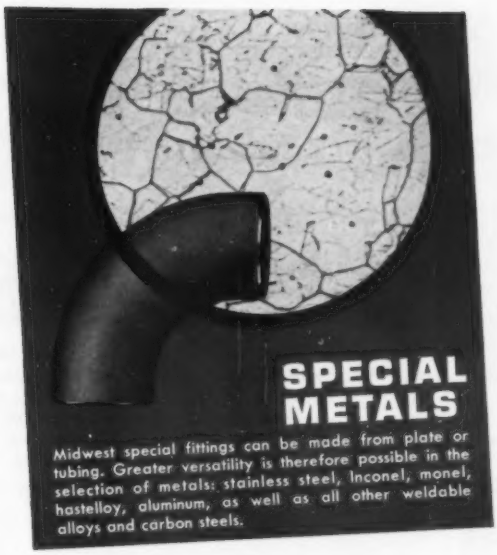
Happenings . . .

of the Whiting refinery, says Standard Oil Co. (Indiana). Whiting is "the first refinery in the history of the petroleum industry to win for the sixth time the National Safety Council's highest-ranking citation Award of Honor." The safety plaque is presented to Whiting refinery manager Arthur F. Endres, right, by Board Chairman Frank O. Prior, as president John E. Swearingen, center, looks on.

This new smog-control automobile muffler was displayed by Universal Oil Products Co. at the recent annual meeting of the Air Pollution Control Association, Cincinnati. The muffler, which is 17 inches in diameter and 4 inches thick, is designed for original installation in new cars or replacement in older ones. It contains a catalyst to convert smog-causing components of automotive exhaust into non-irritating compounds.

L. F. McCollum, Houston, president of Continental Oil Co., is shown chatting with President Eisenhower at a White House conference at which the President announced appointments to the Department of Commerce's new Export Expansion Committee. McCollum, who was appointed chairman of the committee, is also vice chairman of the President's Advisory Council and chairman of that group's International Trade and Commerce Committee.

For more data on advertised products, use Readers' Service Cards, last page.



SPECIAL METALS

Midwest special fittings can be made from plate or tubing. Greater versatility is therefore possible in the selection of metals: stainless steel, Inconel, monel, hastelloy, aluminum, as well as all other weldable alloys and carbon steels.

MIDWEST SPECIAL FITTINGS MADE BY FITTING SPECIALISTS TO YOUR SPECIAL REQUIREMENTS

SPECIAL SHAPES

Midwest's wide experience and skills with forging presses and dies permit forming plate or tubing into unusual shapes for special applications . . . elbows with or without long tangents, wyes, extrusions, and other special configurations.

SPECIAL THICKNESS

Wall thicknesses in a wide range of sizes are available in Midwest special fittings, up to 4", or more in carbon steel and a wide variety of alloys . . . stainless steel, Inconel, titanium, and others.

5946

For special fittings with any or all of the above characteristics, contact your local Midwest distributor . . . or call:

MIDWEST

MIDWEST PIPING COMPANY, INC.

1450 S. Second St. • St. Louis 4, Mo. • MAin 1-8300

For more data on advertised products, use Readers' Service Cards, last page.

NOW

competitively priced!

NEW

Aeromaster
INDUSTRIAL COOLING

FAN

featuring
"QUICK-SWITCH"
BLADES

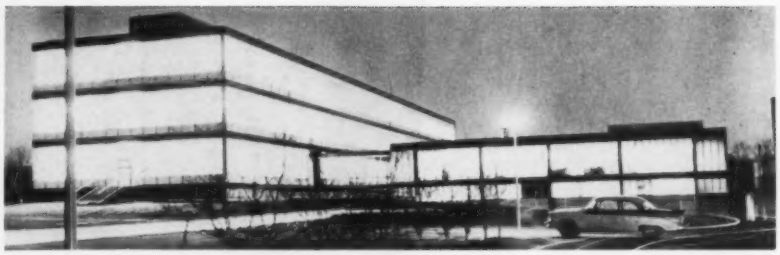
Blades can
be installed
after hub is mounted
on drive shaft

Performance, construction, and price make this the "best buy" in industrial fans! Delivers more CFM with *less* H.P. Features a ductile iron hub, removable blade retention caps, heat treated aluminum alloy blades with constant chord width and flanged ends. 4, 6 and 8 bladed fans available in 54" to 120" diameters. Maximum tip speed is 15,000 ft./min. Easy to install . . . easy to maintain. For complete details, write: KOPPERS COMPANY, INC., 5106 Scott Street, Baltimore 3, Md.

KOPPERS Aeromaster Fans

Engineered Products Sold with *Service*

Happenings . . .



Modern customer-service facilities are in the new Technical Service Laboratory built by Union Carbide Chemicals Co. near Tarrytown, N. Y., in Westchester County. The lab is equipped with up-to-date apparatus to answer scientific, formulation, production, and application questions. The building houses 46 individual laboratory units, plus offices and supporting facilities. In addition, a mechanical test building is fully equipped to conduct large-scale tests and evaluations.

- *Changing Times* -

First annual Industrial Professional Development Award of NSPE has been presented to Phillips Petroleum Co. Engraved plaque was presented at annual NSPE meeting in Boston. Award Committee selected Phillips **for "outstanding advancement** and improvement in the development and application **of forward-looking engineering employment practices."**

Daily average production of natural gas liquids in February was up six percent over February 1959, while production of liquified gases was up nine percent on same basis, according to Bureau of Mines.

President Eisenhower has chastised Congress for not enacting, after four months in session, **his recommendation for five-cent boost in federal motor fuel tax.** Chastisement came early in May, with Ike adding that there are only two months left in session to get job done.

Japan's Ministry of International Trade and Industry has cut by nearly 40 percent requests of companies for **1960 capital investment in petrochemical projects.** Japan has slated $118 million for this purpose.

Cosden Petroleum Corp. has granted license for use of its technique for making polybutene to Naphtachimie, Paris-based organization. Upon completion of polybutene facilities in Europe, **Naphtachimie will be only producer of substance in Europe,** said Cosden spokesman.

Merger has been called off between Texas Butadiene & Chemical Corp. and Industrial Rayon Corp. Large numbers of Industrial Rayon stockholders objected to merger, and had right to cash payment of shares under Delaware appraisal statute.

One of largest lubricating oil contracts ever negotiated in the world of railroading has been signed by Gulf Oil Corp. and Pennsylvania Railroad Co. Gulf will supply company with 2.5 million gallons of diesel lube oil in 1960.

New firm, Parsons Powergas, London, has been formed by The Ralph M. Parsons Co. and P-G Engineering, Ltd., member of the Power-Gas Group. Parsons Powergas will engineer and build petroleum, petrochemical and related plants. Early activities will be in British Commonwealth.

LPG to power diesel locomotives may soon be a reality, says Southwest Research Institute's Engine Fuels and Lubricants Section. Institute says **experimental data show that use of LPG in combination with dual injection system is economically desirable** and technically feasible.

Humble Oil & Refining Co. operated its seven Gulf Coast and East Coast refineries in May at levels 23,000 bpd below same month last year and 11,000 bpd under first quarter average for 1960. First quarter runs were 63,000 bpd below same period in 1959.

Consumers Cooperative Association, Phillipsburg, Kan., has completed four years of operation without lost-time accident—1 million man hours.

An option on 3,000 acres in Brazoria County, Texas, has been purchased by Monsanto Chemical Co. for plant sites. Owned by Houston development company, site is 25 miles from Monsanto's Texas City operation.

If current proposals to tax all aviation fuels equally are adopted, jet planes will

For more data on advertised products, use Readers' Service Cards, last page.

A message to every engineer who wants to
keep fluid mixing costs down

Don't be fooled by *low purchase price* when you specify mechanical mixers for fluids.

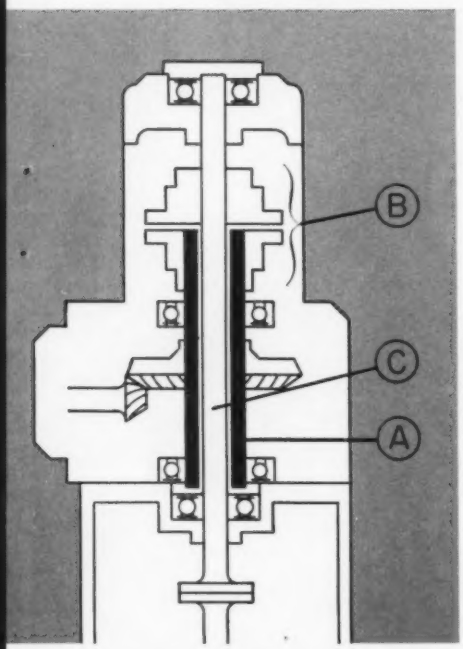
First cost is a very small fraction of your total mixing cost.

To find the *real* savings, look behind the price tag. Which mixer design will give you simplest, cheapest maintenance over the years? Most dependable month-in, month-out service? Greatest adaptability if mixing conditions change? Lowest spare-part requirements?

These are the areas where you can *really* save money on fluid mixing. And here are some of the reasons why you can do it more surely with LIGHTNIN Mixers than with any other mixer available.

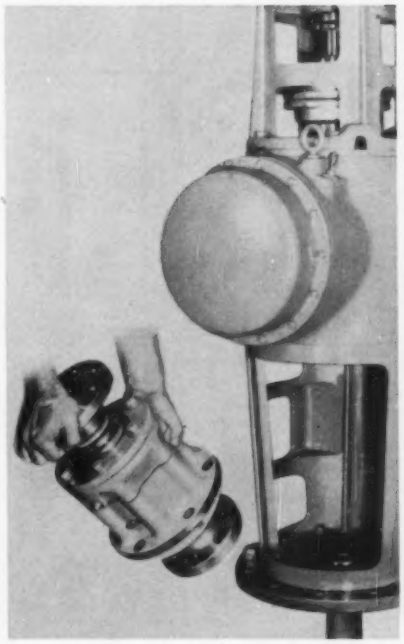
For lower-cost fluid mixing, see your LIGHTNIN representative soon. He's listed in Refinery Catalog. Or write us direct.

Only *Lightnin* Mixers cut your mixing costs these 3 ways



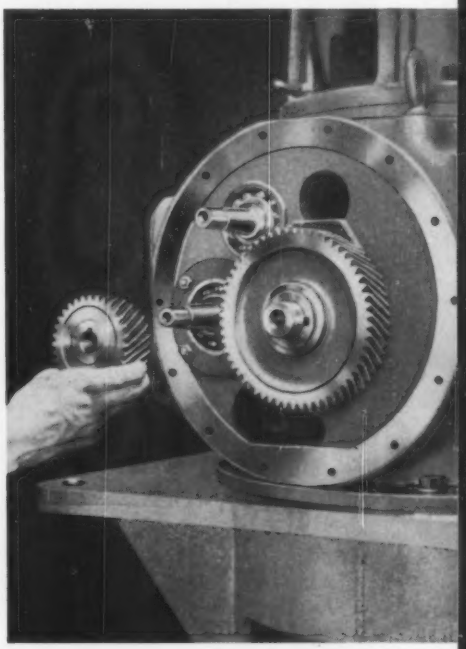
1. PROTECTED GEARING. Ever think what could happen to a mixer's gearing if something in the tank should accidentally damage the shaft? Shocks or flexures *don't reach the gears* in a Series "E" LIGHTNIN Mixer. Hollow quill* (A) isolates gearing from shaft. Flexible coupling (B) transmits power from gears to shaft—soaks up mixer shaft loads. Mixer shaft (C) is easily removed without risk of disturbing gear alignment.

*Patented



2. EASIER, SAFER SEAL CHANGE. Cartridge-type rotary mechanical seal† eliminates leakage under pressure or vacuum, runs for years without adjustment, and can be replaced in minutes without skilled manpower *and without disturbing gearing or shaft alignment.* Basis of this extra safety and convenience is the hollow quill of the reducer, which lets mixer shaft move up and down freely. You get this construction only with LIGHTNIN Mixers.

†Patented



3. INTERCHANGEABLE SPEEDS. Should your mixing requirements ever change (within the mixer's rated limits), you can quickly adapt your LIGHTNIN to meet the new needs. Change gears‡ provide as many as 16 standard AGMA output speeds from the same basic drive. You can change speeds without dismantling the mixer or removing it from the tank. This cost-cutting feature, like all the others shown on this page, is a LIGHTNIN "first."

‡Patented

WHAT MIXING OPERATIONS ARE IMPORTANT TO YOU?
You'll find a wealth of information on fluid mixing in these helpful bulletins describing LIGHTNIN Mixers:

- ☐ Top or bottom entering; turbine, paddle, and propeller types: 1 to 500 HP (B-102)
- ☐ Top entering; propeller types: ¼ to 3 HP (B-103)
- ☐ Portable: ⅛ to 3 HP (B-108)
- ☐ Confidential data sheet for figuring your mixer requirements (B-107)
- ☐ Laboratory and small-batch production types (B-112)
- ☐ Condensed catalog showing all types (B-109)
- ☐ Quick-change rotary mechanical seals for pressure and vacuum mixing (B-111)
- ☐ Side entering: 1 to 25 HP (B-104)

Check, clip and mail with your name, title, company address to:

MIXING EQUIPMENT Co., Inc., 164-f Mt. Read Blvd., Rochester 3, N. Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 19, Ont.

Lightnin® Mixers

MIXCO fluid mixing specialists

Kellogg Design Sets the Pace in

For more data on advertised products, use Readers' Service Cards, last page.

Coker Economy and Efficiency

GREATER FLEXIBILITY OF UNIT DESIGNS PLUS COKING-FREE FURNACE DESIGNS OPTIMIZE END VALUE OF HEAVIEST STOCKS

A Kellogg-designed delayed coker together with a Kellogg-designed furnace offer refiners a most effective and economical way to upgrade bottoms and other heavy stocks.

Kellogg cokers can be designed to operate on virgin crude, atmospheric or vacuum residues, thermal tars, or catalytic cracker cycle stock. As a combination coker-visbreaker, a Kellogg unit can produce either fuel oil or catalytic cracker feed, or both. As a combined coker-flasher tower, it can eliminate the need for a vacuum tower.

Kellogg furnaces reduce downtime for cleaning to a minimum. Continual improvements in designs have long since made frequent turnarounds an expense of the past. With the better heat distribution and dispersement built into Kellogg furnaces, tubes remain virtually coke-free. On-stream efficiency of Kellogg units is close to 95%.

A Record of Coking Accomplishment

Since 1936, Kellogg has engineered, erected, or contracted for 19 delayed or fluid coking units, as shown at right. These represent a total design capacity of 202,365 BPSD and a total coke production capacity of more than 5,893 tons.

Kellogg welcomes the opportunity to discuss with you how this broad experience can be used to advantage in meeting your specific coking requirements.

THE M. W. KELLOGG COMPANY

711 Third Avenue, New York

A subsidiary of Pullman Incorporated

Offices of other Kellogg companies are in Toronto, London, Paris, Rio de Janeiro, Caracas, Buenos Aires

Whiting, Ind.	6,650	BPSD
Ponca City, Okla.	4,785	BPSD
Fort Worth, Texas	6,050	BPSD
Sarnia, Ontario	7,800	BPSD
Oleum, Cal.	20,000	BPSD
Toledo, Ohio	8,500	BPSD
Trenton, Mich.	4,000	BPSD
Torrence, Cal.	26,000	BPSD
East Chicago, Ind.	17,500	BPSD
Buenos Aires, Argentina	18,000	BPSD
Lima, Ohio	19,500	BPSD
Edmonton, Alberta	2,132	BPSD
Amarillo, Texas	3,572	BPSD
Ponca City, Okla.	12,500	BPSD
Tulsa, Okla.	7,000	BPSD
Toledo, Ohio	7,530	BPSD
Lujan de Cuyo, Arg.	18,486	BPSD**
Eldorado, Kansas	8,560	BPSD
Montreal, Quebec	3,800	BPSD*

**Fluid Coker **Future*

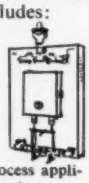
For more data on advertised products, use Readers' Service Cards, last page.

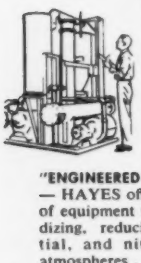
WILLIAM C. DIMAN,
Atmosphere Equipment Specialist, reports . . .

MODERN PROCESSES DEMAND MODERN ATMOSPHERES

Ever since 1927, when C. I. Hayes perfected the first controlled-atmosphere heat treating furnace, we have made a steady effort to further the technology of atmosphere generators and dryers. By recommending proper generators and dryers, we have helped our customers speed production, improve product uniformity and quality and save processing time and trouble. The big Hayes equipment line includes:

MOLECU-DRYER (using LINDE'S Molecular Sieves) — for drying, sweetening, purifying protective atmospheres and for gas and liquid separation and recovery. Exit gas dew points to less than minus 100°F. Many standard sizes available for process applications, instrument air drying, etc.





Linde MOLECULAR SIEVES

NITROGEN GENERATORS (using LINDE'S Molecular Sieves) — produces 99.99% pure inert gas at about 20¢ per 1000 cu. ft. Standard sizes from 1000 CFH to 10,000 CFH.

"ENGINEERED ATMOSPHERES" — HAYES offers a broad range of equipment for producing oxidizing, reducing, carbon-potential, and nitrogen-hydrogen atmospheres . . also engineered equipment packages for stand-by (start-ups, emergencies, etc.). Standard sizes are available in all types Exothermic, Endothermic, and forming gas generators — also ammonia dissociators.

Hayes offers more than just equipment. Our Engineering organization and experimental lab. are ready to help make sure you get the right atmosphere equipment for your work.

ASK FOR BULLETINS . . .	Bulletin No.
Molecu-Dryer	5703-A
Nitrogen Generator	5901-NI
Exothermic Generator	256-A
Endothermic Generator	5808-A
Ammonia Dissociator	5810-D
General Bulletin	5810-GC
Forming Gas Generator	256-A

C. I. HAYES, INC.
Established 1905
853 WELLINGTON AVE., CRANSTON 10, R. I.

ELECTRIC FURNACES

It pays to see Hayes for metallurgical guidance, lab facilities, furnaces, atmos. generators, gas/liquid dryers.

Changing Times (continued)

probably change to gasoline-kerosine blend instead of present straight kerosene. **Blend would be 65 to 75 percent gasoline**—remainder kerosene. Report was made by Texaco's R. H. Tolson at NFPA meeting.

Socony Mobil Oil Co. has reduced U.S. refinery runs 54,000 bpd since beginning of year, stockholders were told at annual meeting.

Merger is being considered between Technical Writing Improvement Society and Western Technical Writing Institute. New association is expected to be management service organization patterned after American Management Association and American Banking Institute.

Houston will be site of API's 1961 midyear meeting of Division of Refining. Dates will be May 8-11. Other tentative sites and dates—1962, San Francisco, May 14-17; 1963, Philadelphia, May 13-16; 1964, St. Louis, May 11-14; 1965, Montreal, May 10-13.

Soviet crude oil has been forced on Standard Oil Co. (New Jersey); Texaco, Inc., and Shell Oil Co., in Cuba. As result of U.S.S.R.-Cuba trade pact, each must purchase 6,000 bpd of the Russian oil for refineries. **Price is to be agreed upon for each shipment.**

Meetings Calendar

June	
19–22	**American Institute of Chemical Engineers,** Meeting, Del Prado Hotel, Mexico City.
19–24	**California Institute of Technology,** Management Development Conference, Campus, Pasadena, Calif.
25-Jul 5	**Instrument Society of America, AACC, ASME, AIEE, IRE, AIChE,** International Congress for Automatic Control, Moscow, U.S.S.R.
26-Jul 1	**American Society for Testing Materials,** Annual Meeting and Apparatus Exhibit, Chalfonte-Haddon Hall, Atlantic City.
Aug.	
14–17	**American Society of Mechanical Engineers-American Institute of Chemical Engineers,** Heat Transfer Conference and Exhibit, Statler Hilton Hotel, Buffalo, N.Y.
Sept.	
7– 9	**ISA, ASME, AIEE, IRE, AIChE,** Joint Automatic Control Conference, Massachusetts Institute of Technology, Cambridge, Mass.
11–16	**California Institute of Technology,** Management Development Conference, Campus, Pasadena, Calif.
11–16	**American Chemical Society,** National Meeting, New York.
14–15	**Western Petroleum Refiners Association,** Rocky Mountain Technical-Industrial Relations Meeting, Henning Hotel, Casper, Wyo.
14–16	**National Petroleum Association,** Annual Meeting, Hotel Traymore, Atlantic City.
–15	**Natural Gasoline Association of America,** Rocky Mountain Regional Meeting, The Palliser Hotel, Calgary, Alba., Canada.
15–16	**ASME,** Engineering Management Conference, Hotel Morrison, Chicago.
18–21	**ASME,** Petroleum Mechanical Engineering Conference, Jung Hotel, New Orleans.
21–23	**ASME-AIEE,** Power Conference, Bellvue-Stratford Hotel, Philadelphia.
25–28	**AIChE** Meeting, Mayo Hotel, Tulsa.
25–28	**American Institute of Electrical Engineers,** Electrical Conference of the Petroleum Industry, Hotel Skirvin, Oklahoma City.
26–30	**American Welding Society,** National Fall Meeting, Hotel Penn-Sheraton, Pittsburgh.
26–30	**ISA,** Fall Automation-Instrument Conference and Exhibit, Annual Meeting, New York Coliseum, New York.
Oct.	
6– 7	**National Association of Corrosion Engineers,** Annual Western Region Conference, Sheraton-Palace Hotel, San Francisco.
6– 8	**NACE,** Southeast Region Conference, Dinkler-Plaza Hotel, Atlanta, Ga.
9–12	**ASME,** Rubber and Plastics Conference, Lawrence Hotel, Erie, Pa.
10–11	**ASME-AIEE,** Fuels Conference, Daniel Boone Hotel, Charleston, W. Va.
11–14	**NACE,** Northeast Region Conference, Prichard Hotel, Huntington, W. Va.
13–14	**California Natural Gasoline Association,** Fall Meeting, Hotel Miramar, Santa Monica, Calif.
25–28	**NACE,** South Central Region Conference, Mayo Hotel, Tulsa.
26–27	**WPRA,** Question and Answer Session on Refining Technology, Rufus Garrett Hotel, El Dorado, Ark.
Nov.	
14–16	**American Petroleum Institute,** Annual Meeting, Conrad Hilton, Palmer House, and Congress Hotels, Chicago.
27–Dec. 2	**ASME,** Annual Meeting, Statler Hilton Hotel, New York.
Dec.	
4– 7	**AIChE** Meeting, Hotel Statler, Washington.
7–11	**NACE,** University of Illinois Corrosion Control Short Course, Urbana Campus.
12–14	**U.S. Public Health Service,** National Conference on Water Pollution, Sheraton Park Hotel, Washington, D.C.

For more data on advertised products, use Readers' Service Cards, last page.

Major refiners report:

IMPROVED DRYING AND PURIFICATION

...WHEN YOU ADSORB WITH LINDE MOLECULAR SIEVES

This is only one of many applications which utilize the high capacity and selectivity of LINDE Molecular Sieves. In fact, Molecular Sieves not only outperform other adsorbents, but do other adsorption jobs never before accomplished. Whether in new installations or as replacement adsorbent in existing units, Molecular Sieves can help you minimize both investment and operating costs. More specifically, here's how they are used. . . .

A major petrochemical company has reduced the CO_2 content of its ethylene from 3000 PPM to less than 1PPM. This high purity is achieved in a single-stage process, automatic and non-corrosive, which has proved to be more economical than the alternative four-stage process. Other petrochemical uses include drying of cracked gases, ethylene, hydrogen, liquid propylene, solvents and many other gases and liquids. **Natural gas producers** use Molecular Sieves for drying and sweetening of natural gas, for sweetening of liquid propane and butane, and for drying of adsorber oil. **Petroleum refiners** use them to gain efficiency in drying reformer hydrogen, liquid butane LPG and transformer oil, and for removal of impurities such as CO_2 and mercaptans **Refrigeration manufacturers** use Molecular Sieves as a desiccant in super-drying refrigerants to eliminate freeze-up and corrosion.

For these and many other adsorbent applications, you can rely on patented LINDE Molecular Sieves to perform more effectively. They are the top quality material of their kind available today, always uniform, with high capacity, high strength, and high bulk density. They are available in regular and special grades to meet your specifications.

LINDE technical know-how—gained from years of laboratory and field work with adsorption problems—can help make Molecular Sieves work profitably for you. For further information, write: Dept. PR-06, Linde Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. **In Canada:** Linde Company, Division of Union Carbide Canada Limited, Toronto 7, Canada.

SOME AREAS WHERE MOLECULAR SIEVES IMPROVE ADSORPTION

- Purification of ethylene
- Drying gases, liquids, solvents
- Drying, sweetening natural gas
- Sweetening liquid propane, butane
- Drying jet fuels
- Octane improvement
- As refrigerant desiccant
- Controlled atmosphere purification

LINDE COMPANY

UNION CARBIDE

"Linde" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

Men In Industry...

LaForce

Boyd

Paul Kayser has been named chairman of the board and chief executive officer of El Paso Natural Gas Co. **Howard Boyd** becomes president, and **Arnold R. LaForce** executive vice president. Boyd was formerly executive vice president, and LaForce was financial vice president. Kayser founded El Paso in 1928, and has since served continuously as its president. Boyd joined El Paso in 1952 as vice president and assistant general counsel. He became executive vice president in 1957, and has been a member of the board since 1953. LaForce joined El Paso as financial vice president and director in 1956.

Kayser

C. W. Rackley has been named assistant chief engineer of Tennessee Oil Refining Co. He has been senior process engineer at the company's Chalmette, La., refinery. To be transferred to the Houston headquarters office in July, he will be replaced by **A. R. Dudley, Jr.,** senior process engineer, who is transferring to Chalmette from Houston. **A. E. Bynum,** formerly junior engineer at Chalmette, has been promoted to assistant process engineer there.

Leonard Wilkins has been appointed director of engineering for Texas Butadiene & Chemical Corp. He will be in charge of all project engineering, with offices in Houston. With Koppers Co., Inc., for 18 years, Wilkins, a graduate of Georgia Tech in chemical engineering, was most recently a project manager on a petrochemical plant to be built at La Plata, Argentina.

Herman G. Gunter has been named vice president and general manager of refinery operations, Commonwealth Oil Refining Co., Inc. Previously assistant refinery manager, he joined Commonwealth a year ago. He has had more than 30 years' operating experience in the oil industry. Previous associations include affiliates of Standard Oil Co. (New Jersey), Suntide Refining Co. and Continental Oil Co.

Clifford B. Marshall has been elected executive vice president of Standard-Vacuum Oil Co. He is the first to carry this title in Stanvac's history. A director since 1949 and a vice president for eight years, he also has been vice chairman of the executive Committee. Marshall started his petroleum industry career in Ceylon nearly 41 years ago following graduation from Denison University in Ohio. After serving several years each in Madras, Calcutta and Bombay, he became the company's general manager in charge of marketing operations in India, Pakistan, Burma and Ceylon in 1944. Marshall is president of the Far-East America Council of Commerce and Industry, Inc., and a director of the International Schools Foundation, Inc.

Monroe Jackson Rathbone, president of Standard Oil Co. (New Jersey), has been named chief executive officer and chairman of the Executive Committee. He retains the presidency, a post he has held since 1954. Rathbone succeeds as chief executive officer **Eugene Holman,** board chairman, who has retired. Succeeding Holman as chairman of the board is **Leo D. Welch,** an executive vice president, who joined Jersey as treasurer in 1944 after a 25-year career in foreign banking. Welch will be vice chairman of the Executive Committee. **M. A. Wright,** a director since 1958, was elected an executive vice president and a member of the Executive Committee.

Breyer

Finkeldey

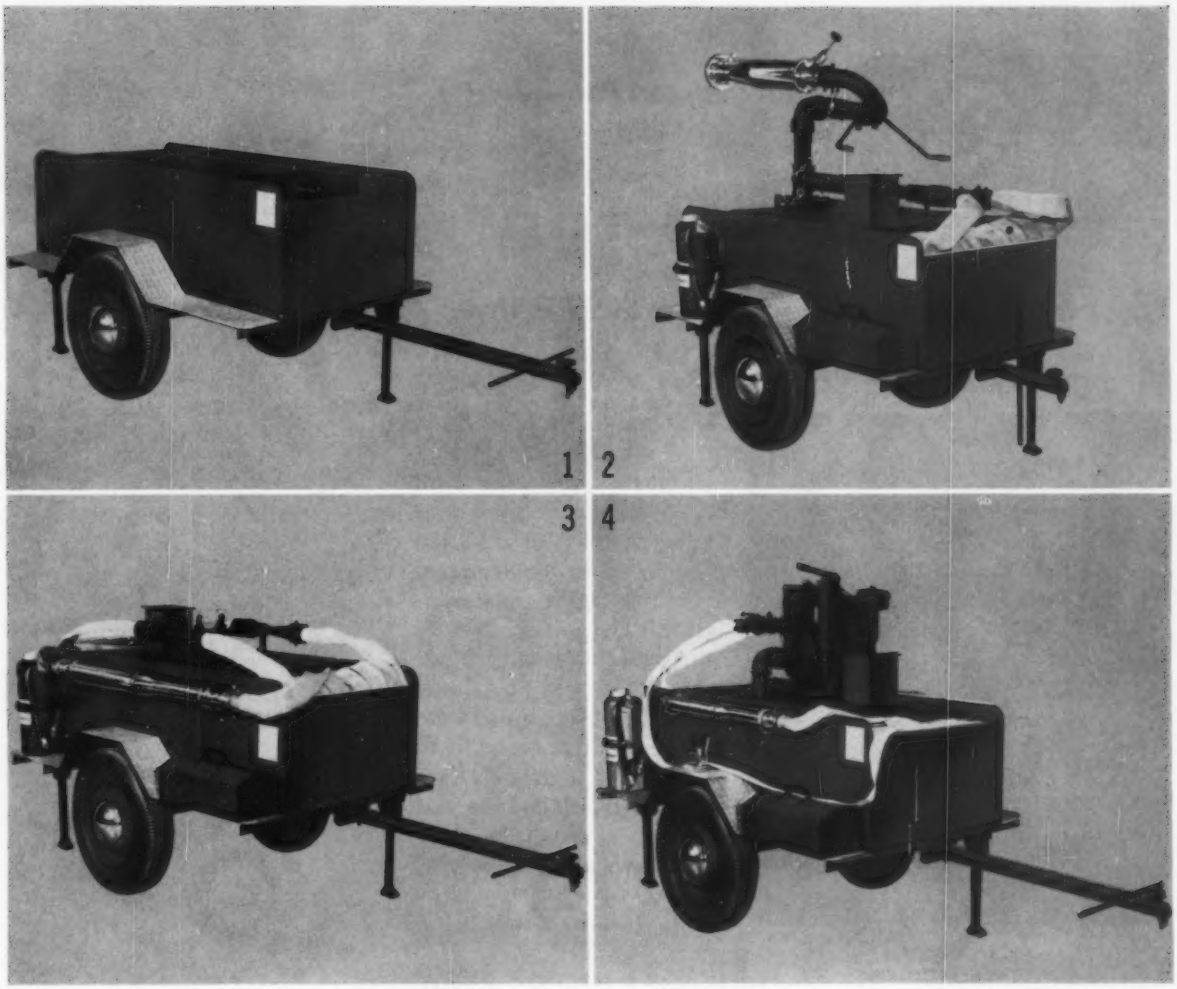
Byron Marquis has been appointed president of Singmaster & Breyer, Inc. He was formerly vice president of engineering. **Frank G. Breyer,** previously chairman of the board, becomes chairman of the advisory committee, and **William H. Finkeldey** moves from the presidency to chairman of the board. Marquis has been a Singmaster & Breyer partner since 1945. Breyer and **James A. Singmaster** founded the firm, and Finkeldey, a metallurgist, has been a company partner since 1927.

Marquis

R. W. McDowell has been named chairman of the board, Sunray Mid-Continent Oil Co. **C. H. Wright,** formerly board chairman, becomes chairman of the Finance Committee. **S. D. Breitweiser,** formerly executive vice president of DX Sunray Oil Co., was named president of that company, succeeding McDowell. McDowell has been with Sunray and predecessor companies more than 36 years. He became division manager for the former Mid-Continent Petroleum Corp. in 1927. He became sales vice president in 1930, and president in 1949. After the merger of Mid-Continent and Sunray Oil Corp. in 1955, he became president of DX Sunray Oil Co. and vice-chairman of the board, Sunray Mid-Continent Oil Co. Breitweiser joined DX Sunray in 1957 as vice president of marketing. He was elected executive vice president of all DX Sunray operations in May 1959. Before joining DX Sunray, he was vice president and director of Vickers Petroleum, Inc., Wichita. He spent 22 years of his professional life with Continental Oil Co.

Noyes Richey, Texas Butadiene & Chemical Corp., has been promoted from associate professional research chemist to section head, Polychemical Department laboratory, Miami, Fla. He will be responsible for establishing analytical characterization techniques for new products to be developed and marketed by the department. Before joining T B & C in 1956, he was with Cities Service Oil Co. He is a graduate of Southwestern Louisiana Institute, and is a member of ACS and ISA. **Albert L. Remsberg,** Manufacturing Research Department chemist, will become analytical characterization chemist. With T B & C for 3½ years, he is a graduate of Kansas State College, and was previously with Allied Chemical Corp., Orange, Texas. He is a member of ACS. **Robert E. Parks,** a chemist, will work with Richey and Remsberg. He has been with T B & C for 2½ years. A graduate of Southwest Texas State College, he is a member of ACS.

Harold S. Skinner, assistant to the president and director of public affairs, Continental Oil Co., has been promoted to manager of public affairs and public relations. He will also become a member of the company's Management Executive Committee. **Emerson G. Smith,** currently director of public information, will continue in that position. **John Post,** manager of industrial relations, was promoted to director of industrial and personnel relations. He will be special advisor to the president on industrial and personnel relations. The name of the Industrial Relations Department will be changed to the Personnel Relations Department. **Vance A. Knight,** currently assistant manager of industrial relations, will be manager of personnel relations.



the most **fire protection** *ever carried on two wheels!*

Need an inexpensive utility trailer built to meet specific needs? National Foam has it!

Here's a versatile, variable vehicle designed so that it can be custom-equipped to fit the requirements of any user . . . industrial, municipal, or volunteer.

Your choice of tank capacity: 100 gallons or 150 gallons. Extendable drawbar makes it easy to pull by hand. There's also a ball-and-socket hitch for towing. Capacious bins, for fire hose or accessories, are built-in fore and aft.

Think how this basic cart (Photo 1) adapts easily to special needs: (Photo 2) Add a monitor-mounted PW-50 Nozzle, with line proportioner. With Aer-O-Foam Liquid in the tank and 150-pound pressure from hydrants, you can throw a 4000 GPM foam stream as far as 180 feet. You can pump foam steadily as long as 10 to 15 minutes. Add a tool box and dry chemical extinguishers and you're equipped to combat a wider range of fires.

(Photo 3) If manually operated nozzles are preferred, mount two RP-12 Nozzles, connected to suitable line proportioners. This same foam cart also serves as a source of foam liquid for foam chambers on small storage tanks.

(Photo 4) Use the tank for water, add a gasoline-powered pump, and draw Aero-O-Foam Liquid if needed from 5-gallon containers carried in the cart's storage bins.

Maybe your situation calls for still another variation . . . including many outside the fire protection field, such as weed killing. National Foam's engineers are ready to help with specifications and designs. Send your inquiry today.

National Foam System, Inc.

West Chester, Pa.

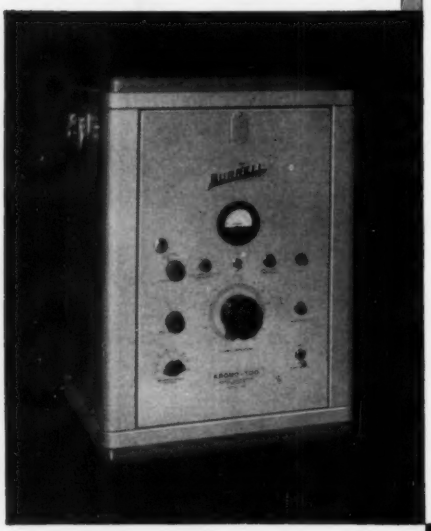
For more data on advertised products, use Readers' Service Cards, last page.

BURRELL "For Scientists Everywhere"

THE KROMO-TOG®

MODEL K-3

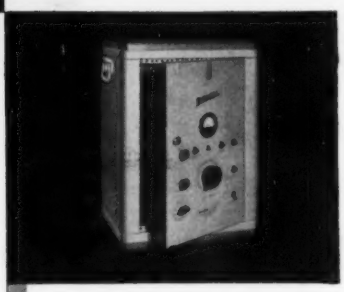
for gas and vapor chromatography



The Kromo-Tog, Model K-3, is a compact, low-cost, chromatographic instrument for the speedy routine analyses of most gases and liquids of any boiling point to 370° C., and over.

Accessories may be added to the basic "build-up" unit. Panel-door and sides open for free access to all components. Extremely easy to install and use, this model may be bench or panel-mounted anywhere.

- **SEPARATE COLUMN TEMPERATURE CONTROL**
- **ACCESSIBLE COLUMNS FOR RAPID CHANGE**
- **HIGH SENSITIVITY OF DETECTOR CELL**
- **FRACTIONS AND CUTS EASILY COLLECTED**



THE BURRELL KROMO-TOG

Model K-3

Basic chromatographic unit,
less recorder or power source for cell.
Operates at 115 volts, 60 cycles.

Burrell Cat. No. 340-30-01.....$990.
F.O.B. Pittsburgh, Pa.

COMPACT SIZE
Only 24" x 16" x 13"

BUILD-UP DESIGN
Accessories can be added.

Ask for Bulletin 831

BURRELL CORPORATION
Scientific Instruments and Laboratory Supplies
2223 FIFTH AVENUE, PITTSBURGH 19, PA.

Men . . .

Parker

Carter

F. Drake Parker, formerly a vice president of Arthur G. McKee & Co., has been appointed managing director of McKee Head Wrightson, Ltd., with headquarters in London, England. **Douglas H. Carter** becomes director and general manager of the British concern. He was formerly director and general manager of Head Wrightson Processes, Ltd.

W. R. Stott and Herbert Willetts have been elected to the board of API. The board also elected **Morgan J. Davis,** president of Humble Oil & Refining Co., Houston, to its Executive Committee. Davis has been a board member since 1957. Stott, a vice president of Standard Oil Co. (New Jersey), replaces **Eugene Holman** on the board. Willetts, president of Mobil Oil Co. and executive vice president of Socony Mobil Oil Co., Inc., replaces **R. L. Minckler,** senior vice president of Mobil Oil Co., Los Angeles. Minckler served on the board since 1949.

Guy D. Carroll, former Northern Region manager for Standard Oil Co. (Indiana), has been named Baltimore Region manager for American Oil Co. He joined Indiana Standard, parent of American Oil, in 1930 as a warehouse clerk in Terre Haute, Ind. Assignments of increasing responsibility took him to Kansas City, Chicago, Huron, S. D., and Grand Rapids, Mich. He was named manager of sales promotion and sales training in Standard's general office in Chicago in 1957. He moved to Milwaukee as regional manager in 1959.

Lawrence A. Kimpton has joined Standard Oil Co. (Indiana) and will undertake special assignments. The move will be effective when his successor as chancellor of the University of Chicago is elected. He resigned in March after nine years as chancellor. Kimpton has been a member of Indiana Standard's board for two years. He will travel in the United States and abroad to study the company's facilities and operations.

P. S. Magruder has been named assistant to the president of Mobil Oil Co. Executive vice president of General Petroleum Corp. until the merger of that company with Mobil, he will be the personal representative of Mobil's president, **Herbert Willetts.** He will reside in Los

For more data on advertised products, use Readers' Service Cards, last page.

IN A FIVE-MINUTE TELEPHONE CONVERSATION . . .

This gas processing specialist helped an operator save $3,000 a day

Recently, a West Texas natural gas processor called stating he was flaring sales gas due to high sulfur content caused by foaming in an ethanolamine system. The same antifoamants used successfully for some time were not effective. Subsequent questioning revealed that his gas stream was now at a higher temperature than the amine and a condensation of hydrocarbons resulted. On-the-phone-solution . . . raise the amine temperature to approximately 15° F. above that of the gas stream.

This, of course, was a simple one. More often Jefferson's experienced gas treating specialists will probe for pertinent data, request samples, and coordinate the solution of your problem through Jefferson's Austin Laboratories. Whether your problems be in desulfurization or dehydration . . . corrosion, foaming or contamination . . . Jefferson can draw on a vast fund of case experiences to help you avoid costly shutdowns, gas flaring or excessive solution losses.

For the *right* gas processing answers and chemicals . . . call Jefferson Chemical Company, Inc., 1121 Walker Avenue, P. O. Box 303, Houston 1, Texas.

Ethylene and Propylene Oxides, Glycols, Dichlorides, Carbonates
SURFONIC® Surface-Active Agents • Ethanolamines • Morpholine
N-Alkyl Morpholines • Polyethylene and Polypropylene Glycols
Piperazine • Piperazine Salts • Nonyl Phenol • Caustic Soda
HOUSTON • NEW YORK • CHICAGO • CLEVELAND • CHARLOTTE • LOS ANGELES

JEFFERSON CHEMICALS

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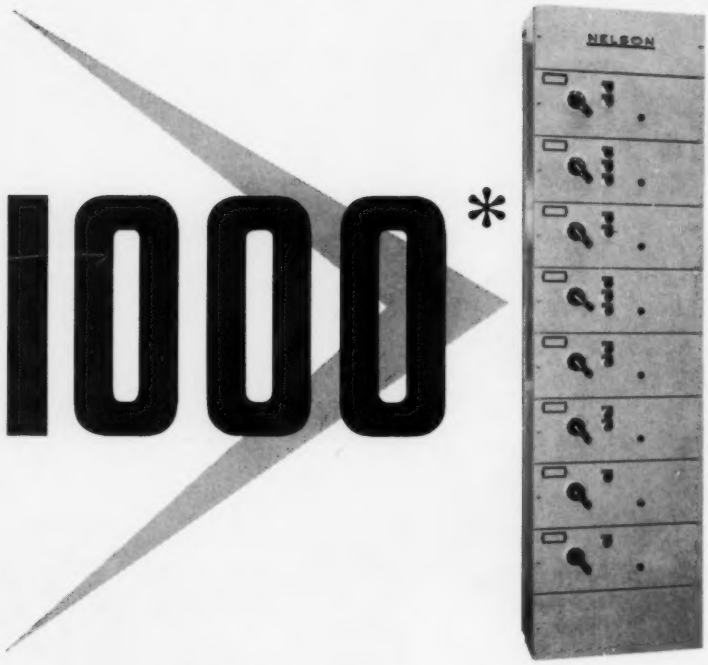


1000 — *that's the number of Motor Control Center structures* Nelson has supplied to a single industry in just the last 5 years.**

What better evidence of complete satisfaction could be desired? Nelson equipment is designed for complete dependability, easy installation, *and* is priced right.

This record of proven performance again confirms the fact that Nelson is

BIG ENOUGH TO PERFORM SMALL ENOUGH TO CARE

Be sure to let your Nelson representative figure your next job. You will find him listed in the Yellow Pages of major city telephone directories.

If *quick shipment* on Motor Control Centers is of importance to you, ask for a copy of Nelson's new *QUICK-TROL* Bulletin.

** *Ask your Nelson man for the name of the industry and the facts.*

NELSON *Electric* MANUFACTURING CO.
TULSA, OKLAHOMA
P. O. BOX 5385 RIVERSIDE 2-5531

Men . . .

Angeles and will be principally concerned with the Pacific Coast area. Magruder will be proposed by Mobil to fill the vacancy on the board of directors of Western Oil and Gas Association created by the retirement of **Robert L. Minckler,** senior vice president, Mobil. He will also represent Mobil on the board of governors of the Pacific Oil Institute and other business and industry groups in the West. Magruder joined General Petroleum in 1925. He became manager of manufacturing and a director in 1945, became a vice president in 1946, and executive vice president in 1948.

Thomas

Wreyfield

Dr. B. W. Thomas has been elected director of Texas Butadiene & Chemical Corp.'s new Instrumentation Physics Research Department, Houston. **Donald M. Wreyfield** will be section head in the department, which will be responsible for process instrumentation development and application. Dr. Thomas is a Pennsylvania State University graduate, and was previously with Humble Oil & Refining Co. Wreyfield has been with Texas Butadiene four years. He is a graduate of Hardin-Simmons University, and was previously with Perkin-Elmer Corp.

Robert W. Wilson has been named patent counsel for Goodrich-Gulf Chemicals, Inc. He comes to Goodrich-Gulf from The B. F. Goodrich Co.'s Patent Law Department. Wilson has a B.S. degree in chemical engineering from the University of Wisconsin. He joined B. F. Goodrich in 1942 as a chemical engineer and, after studying at Akron Law School, joined the company's Patent Law Department as a patent specification writer. He became a patent attorney in 1948. In 1952, he went to the Plaskon Division of Libby-Owens Ford Glass Co. as a patent counsel, and later entered private practice in Detroit. He returned to B. F. Goodrich in 1955, doing patent work for Goodrich Chemical and Goodrich-Gulf.

Sidney M. Brunson has been named project manager for engineering and construction of the new ethylene dichloride plant of C.S.R.C. Dow Pty., Ltd., Melbourne, Australia. He will direct detailed engineering, and when this is completed will move to Australia to supervise

For more data on advertised products, use Readers' Service Cards, last page.

Photographed at Standard Oil of Ohio, (Toledo Refinery)

The constant challenge and the continuous answer

The demand for ever-superior fuels from refiners is constant. The search for ever-better catalysts to help produce these fuels is continuous. At the oil companies and at Cyanamid, the searchers have found that each challenge can best be met by pooling knowledge and resources. In a word, the continuous answer lies in *cooperation.*

Cooperation with refiners helped Cyanamid develop an answer in Aerocat® micro-spheroidal synthetic catalyst. Aerocat provides high activity, stability, and selectivity through controlled physical properties. You can depend on Aerocat for efficient overall performance and satisfactory product realization.

The Cyanamid sales representative–the Man with the Golden Rule–played an important role in developing Aerocat and other catalysts. His job is not simply to sell. His job is to help you in your continuous task to meet the constant challenge. Behind his knowhow are the resources of a major catalyst producer that is also a major manufacturer of other chemicals – Cyanamid. Call when you need the aid of his skill.

Basic in catalyst chemistry

CYANAMID

AMERICAN CYANAMID COMPANY • REFINERY CHEMICALS DEPARTMENT • 30 Rockefeller Plaza, N. Y, 20, N. Y.

DEKORON PROTECTO-PAC

Advantages of Dekoron all-plastic instrument tubing harness are *now four-dimensional.* You get, in addition to its inherent lower-cost installation . . . chemical . . . impact . . . fire resistance.

And the advantages of Dekoron Protecto-Pac multiply the closer you examine them. For example, you can get Protecto-Pac in many forms to suit your requirements exactly — *from stock.*

If there is danger from weld splatter, sparks or a potential fire hazard — order Dekoron Protecto-Pac Type FB. If you wish to bury it underground — specify low-cost Protecto-Pac Type B. Both types supplied with virtually any number of individual tubes, and also with *new metal armor protection.*

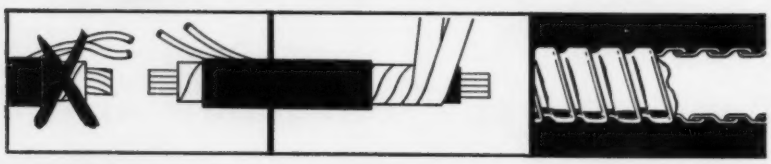
You can pay more but you can't buy better, longer-lasting instrument line harness than *Dekoron — America's Premier Instrument Tubing Line.*

AA-8886

TYPE FB
FOR FIRE AND IMPACT RESISTANCE

FIRE RESISTANCE of copper tube bundles is superior up to 1900°F; less pronounced from 1900° to 2500°F. Above 2500° Protecto-Pac Type FB is superior to copper tube bundle.

TYPE B
FOR UNDERGROUND BURIAL



NO "CORKSCREW" effect, as with twisted tubes, because tubes lie straight in bundle to give faster, neater individual tube take-offs.

NEW IMPROVED INSULATION is composed of two wraps of asbestos tape bonded to backing of Mylar® for maximum protection.

DEKORON PROTECTO-PAC Type FB or Type B can be supplied with 24 gauge galvanized steel armor of modified square-lock construction with cord packing for maximum strength and flexibility.

Dekoron® products QUALITY • RESEARCH • SERVICE

SAMUEL MOORE & COMPANY • DEKORON PRODUCTS DIVISION • MANTUA, OHIO

Men . . .

construction and start-up operations. Brunson joined Dow's Texas Division, Freeport, in 1953 and was assigned to the Vinyl-Vinylidene Chloride Department as a research and development engineer. In 1956 he became planning engineer, and in 1957 became assistant production superintendent of the department. He held the latter position until his present assignment. Before joining Dow, Brunson worked for Diamond Alkali Corp.

Edwin G. Graeber has been named technical director in charge of process engineering for Arthur G. McKee & Co.'s Refinery Division. He will be responsible for process design of refineries, chemical and petrochemical plants. A graduate of Pennsylvania State University, from which he received a M.S. degree in 1934, Graeber had previously spent nine years with McKee as assistant chief process engineer. Most recently he was with Air Reduction Co., Inc., as chief process engineer. Before joining McKee for the first time he was a senior process engineer with The Lummus Company.

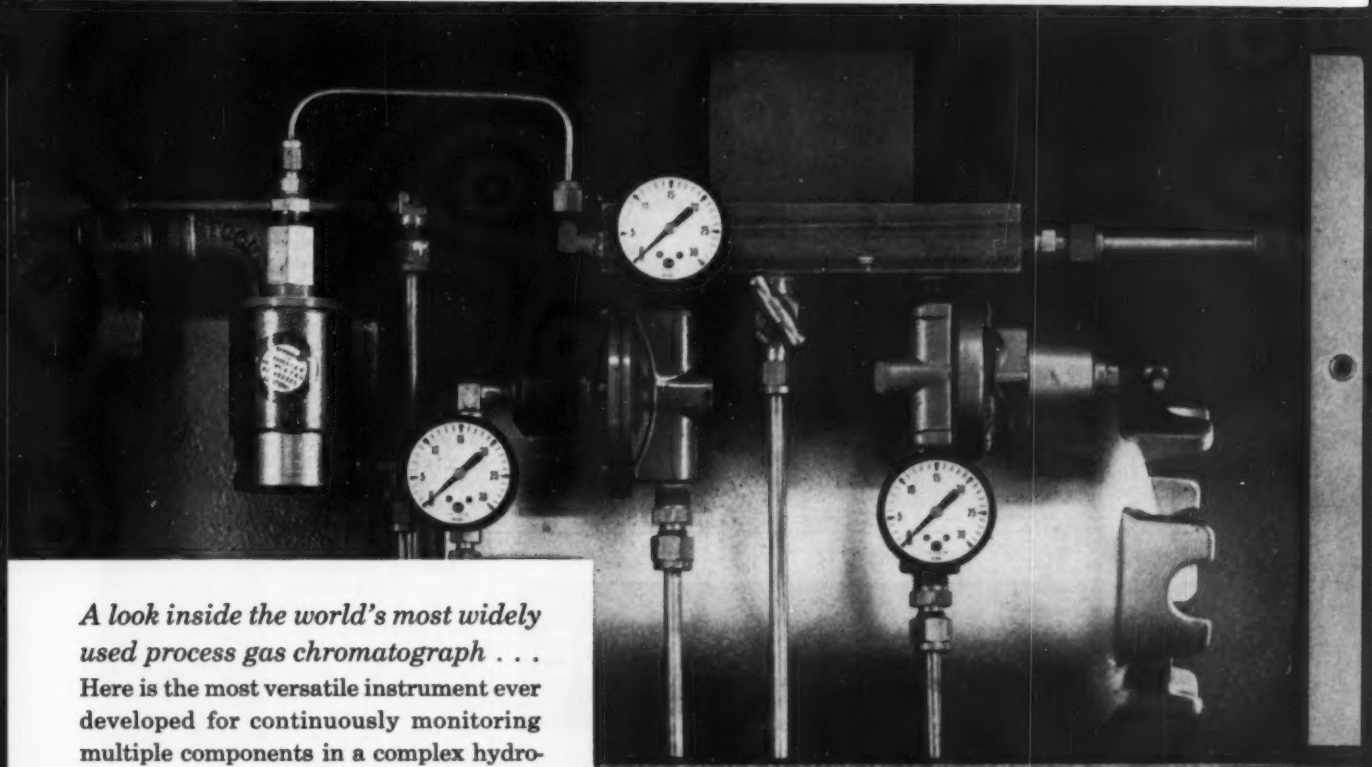
Graeber

J. L. Tveten has joined Humble Oil & Refining Co.'s Research and Development Division, Baytown, Texas. He is to receive his Ph.D. degree in organic chemistry from the University of Illinois in June. **Pramote Chaiyavech,** who holds a B.S. degree in chemistry from Chulalongkorn University, Thailand, and will receive a Ph.D. degree in chemical engineering from The University of Texas in June, is working for three months in the Technical Division.

Thomas E. O'Hare has been named staff engineer-economist by The M. W. Kellogg Co. He will be responsible for directing and making economic studies in various fields of Kellogg engineering activity, including chemicals and oil refining. O'Hare holds a M.B.A. degree from The New York University and is a chemical engineering graduate of The City College of New York. He has been with Kellogg since 1954.

Marlin E. Sandlin, Houston, formerly vice president and general counsel for Great Northern Oil Co., has been named chairman of the board. He replaces **J. R. Parten,** also of Houston, who has retired. **Randall G. Dunn,** Wichita, Kan., has been elected to the board.

Dr. E. M. Adams, The Dow Chemical Co., Midland, Mich., has been elected chairman of the Manufacturing Chemists' Association's Air Pollution Abatement Committee. He succeeds **A. B. Pettit** of W. R. Grace & Co. **O. C.**



A look inside the world's most widely used process gas chromatograph . . .
Here is the most versatile instrument ever developed for continuously monitoring multiple components in a complex hydrocarbon stream... the Beckman Industrial Gas Chromatograph. Its pneumatic heating system, in an explosion-proof housing, provides close temperature control (±.1°C.) for long-term analysis reproducibility. Accessible design simplifies and speeds adjustment when required. And accessories broaden its range of refining applications. ⌘ Application engineers run new instruments on samples from your stream to guarantee performance on your process ...*before* delivery. Beckman Industrial Gas Chromatographs are delivered ready to go, with start-up a regular service. ⌘ The result is continuous, trouble-free operation on a variety of refining streams to give vital information for process control ...the real reason why Beckman Process Chromatographs outsell all others combined. ⌘ For detailed instrument specifications and answers to your process control problems... write for data file 25-6-07.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road,
Fullerton, California

It's a Fact: While a cat cracker produced enough gasoline to power every automobile in the U.S. for 200 miles, a Beckman Oxygen Analyzer continuously monitored the catalyst regeneration with only routine cleaning and adjustment required.

Men . . .

Thompson, Union Carbide Corp., South Charleston, W. Va., is the new vice chairman, succeeding **Elmer P. Wheeler,** Monsanto Chemical Co., St. Louis. Thompson serves also as chairman of the association's Water Pollution Abatement Committee.

John T. McCoy of New York and **John W. Newton** of Texas, were presented Certificates of Appreciation at the 25th midyear meeting of API. McCoy is coordinator of Tidewater Oil Co.'s Eastern Division Manufacturing Department. Newton is president of Norvell Wilder Supply Co., Beaumont, Texas. Formal presentations were made at the division's traditional dinner meeting May 11.

M. L. Crow has been promoted to staff engineer, **W. N. Lyster** to senior chemical engineer and **E. M. Simmons** to foreman of the Physical Testing Laboratory, Technical Division, Humble Oil & Refining Co.'s Baytown, Texas, refinery. Crow holds a B.S. degree in mechanical engineering from Texas A&M College and Lyster a B.S. degree in petroleum refining engineering from Colorado School of Mines.

Dillon Anderson has been elected to the board of Monsanto Chemical Co. He is a partner in the Houston law firm of Baker, Botts, Andrews & Shepherd and is board chairman of Texas National Bank, Houston. Anderson holds a B.S. degree from the University of Oklahoma, LL.B. degree from Yale University and honorary LL.D. degrees from Texas Christian University and Allegheny College.

William B. Hudson, Jr., has been named vice president in charge of refinery engineering for Arthur G. McKee and Co. He will be responsible for estimating and for for the process and mechanical design of refineries, chemical and petrochemical plants. A 1941 graduate of Drexel Institute of Technology, Hudson was previously with Foster Wheeler Corp. for 19 years in various technical and executive positions. In recent years he had been manager of the firm's Petroleum Refinery Department and manager of foreign operations. Hudson is a member of AIChE.

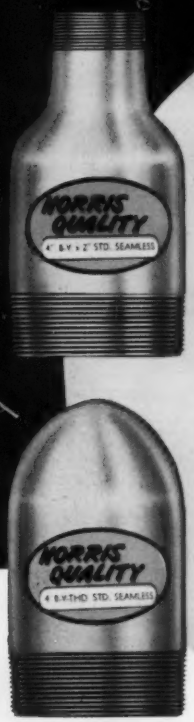
Hudson

Gordon W. Jones has been appointed assistant vice president and director of construction, The M. W. Kellogg Co. He will be responsible for all construction activities in North and South America and for development of construction methods for world-wide use. He was formerly manager of technical services. Jones joined Kellogg in 1929. His first construction assignment was in 1933 as field engineer. Later he was resident manager on many projects including a $65-million refinery in Australia, a refinery complex in Scotland, a lube oil plant in the United States and refinery units both in the United States and abroad. In 1955, he was appointed construction manager of Kellogg International Corp., Ltd., London.

Jones

Now turn to Page 310 and read "Suppliers Notes" to keep informed about those who supply and service the industry.

PROVEN BY EXPERIENCE



W. C. NORRIS SWAGED NIPPLES and BULL PLUGS

Safety . . . craftsmanship . . . durability . . . precision . . . yes, these elements are important in Swaged Nipples and Bull Plugs. And, these are the elements found in *all* W. C. Norris fittings — elements proven by the experience of our customers.

W. C. NORRIS, MANUFACTURER
DIVISION OF DOVER CORPORATION
P. O. BOX 1739 • TULSA, OKLAHOMA
BRANCHES: Great Bend, Kansas; Corpus Christi, Houston, Kilgore, Odessa, Wichita Falls, Texas; Oklahoma City, Oklahoma; Salem, Illinois; Casper, Wyoming; Farmington, New Mexico; Edmonton, Alberta, Canada.

NORRIS QUALITY OIL WELL SUPPLIES

Buy From Your NORRIS Distributor

For more data on advertised products, use Readers' Service Cards, last page.

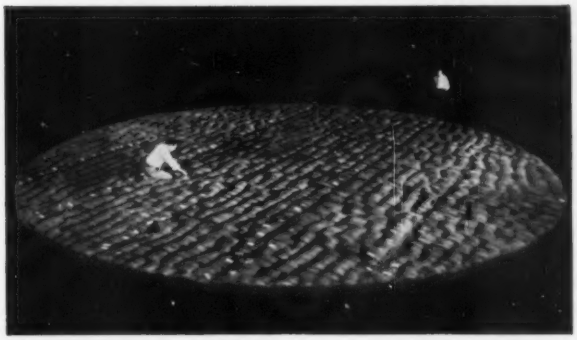
METEX MIST ELIMINATORS

...the First name in knitted wire entrainment separators!

FIRST with strip-type construction
FIRST with wound-type construction
FIRST with Hi-Thruput® mesh
FIRST with fiberglas coalescers
FIRST with all-metal coalescers
FIRST with polyethylene
NOW FIRST with Teflon®

Since 1943, when it first introduced knitted wire entrainment separators—Metal Textile has been consistently first in introducing new developments to the field. In response to requests from chemical and processing engineers throughout industry—Metex engineers have utilized new materials...developed special meshes ...initiated revolutionary techniques to provide low-cost, high-efficiency answers to the most complex entrainment problems. Your specific needs can be similarly solved. Our engineers, backed by the most extensive research and production facilities in the field, will be glad to recommend the type of Metex Mist Eliminator and method of installation best suited to your particular operating conditions. For latest design guides, write or call for Bulletin ME-9: Metal Textile Corporation, Roselle, New Jersey.

38′ dia. Metex Hi-Thruput Mist Eliminator for world's largest vacuum pipe still.



METAL TEXTILE CORPORATION
...world's largest and oldest producer of knitted wire products
A DIVISION OF GENERAL CABLE CORPORATION

Skilled Hands Know the Difference...

Genuine RIDGID®

At Your Supply House!
The Ridge Tool Company, Elyria, Ohio, U.S.A.

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers Notes...

As part of its field force expansion program, Crouse-Hinds Co. is training a group of product engineers at its Syracuse, N. Y., plant. They are studying all four of the company's product lines, and will return to field offices across the country to continue on-the-job training.

BROWN INSTRUMENTS DIVISION has joined other Century Club members of the Scientific Apparatus Makers Association. **Dr. George A. Downsbrough** (left), SAMA president, presents membership certificate to Brown's **Vice President Henry F. Dever** at association's recent annual meeting at Boca Raton, Fla.

BUCYRUS-ERIE CO. has reported a 67 percent over-all increase in machine bookings during 1959, reflecting an "improved level of business in all product lines." Shipments were $75.4 million, up 29 percent over 1958.

ATLAS POWDER CO. has elected **Max E. Colson** and **Edward J. Massaglia** to its board. Colson is a vice president, Explosives Division, and Massaglia is vice president and general manager, Chemicals Division.

ATLAS POWDER CO.'s new 1959 earnings rose nearly 36 percent to $3.9 million. The earnings, equivalent to $5.15 a share, were achieved on near-record sales and operating revenues of $70.7 million, up 7.8 percent from 1958.

LAYNE & BOWLER, INC. has named **Frank T. Quinn** (left) president of the company, and **John M. Proos** (right) chairman of the board. Proos will continue as vice president of Layne-Northern Co., Inc. Quinn, with the company 34 years in sales, advertising and manufacturing, had been vice president of manufacturing since 1957.

SCHUTTE AND KOERTING CO.'s Instrument Division has established an Export Department, to be supervised by **William F. Singer, Jr.** To be located in Philadelphia, it will handle sales and engineering service of flow meters and indicators.

PARKER SEAL CO. has appointed **Joseph Kist** European Area representative, to cover all of Free Europe. He was formerly with Fokker, Royal Netherlands Aircraft Factory, as a service representative. Kist will headquarter in Amsterdam.

ALLIS-CHALMERS MANUFACTURING CO.'s Control Department has appointed **D. B. Scott** manager, succeeding **F. C. Ludington,** retired. With the company since 1937, Scott became assistant manager, Rectifier Section, in 1955, and manager in 1958.

CALUMET & HECLA, INC.'s Wolverine Tube Division has appointed **Ralph J. Brown** manager, employe and public relations. With Wolverine since 1951, he had been training supervisor, Detroit plant, and industrial and public relations manager, London, Canada.

NOWERY J. SMITH CO. has added **Isham L. Harrison** and **Ralph B. Cushman, Jr.,** to its Special Coatings Division sales force. Harrison was previously with Field Erection & Welding Co., while Cushman was formerly with A. C. Horn Co. of Texas.

UNITED STATES STEEL CORP.'s National Tube Division has named **James E. McDonald** manager, mechanical and pressure tubing products. He attended Indiana University, served in the Army, 1943-46—then joined National Tube Division.

TRACERLAB CO. has named **Leonard F. Tischler** assistant manager of contract sales. He will procure and administer all special contract business for the Western Division, Richmond, Calif.

SNAP-TITE, INC. has created new Midwestern and Western sales divisions and appointed managers to supervise its three sales districts. **Tom Welsh** will have the Western Division, **L. R. Finn** Midwestern Division, and **Harold Fisher,** Eastern Division.

THE BABCOCK & WILCOX CO. has signed a dealer sales agreement with The Denver Fire Clay Co., which will market B & W's refractories in Colorado, Wyoming, New Mexico, Utah, Eastern Nevada, Idaho and Western Montana.

Fullingim

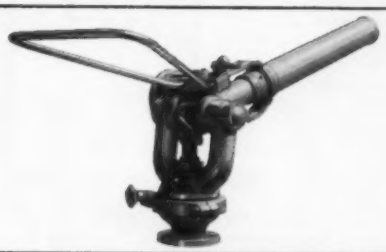
Grigsby

CONTINENTAL-EMSCO CO.'s Robert J. Grigsby has been promoted from D&B specialist to store manager, New Harmony, Ind. Grigsby began his employment in 1952 as a warehouseman. He has also been a field salesman. Also promoted to store manager is **Leroy E. Fullingim,** Luling, Texas. He joined Continental-Emsco as a sales trainee in 1948. He has also served as a D&B storeman, service engineer, field salesman and D&B specialist. **Raymond M. Lewis,** former field salesman, is now D&B specialist in Sundown, Texas. **Richard E. Walker** has been promoted from field salesman to D&B specialist in Newcastle, Wyo., and **Theodore D. Phillips** from field salesman to D&B specialist in Salem, Ill.

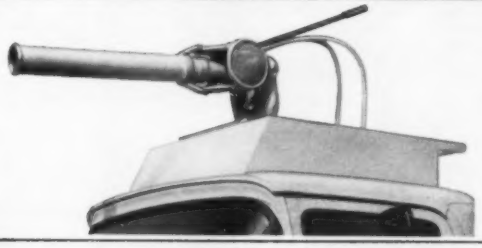
Most Complete Line of Specialty Turrets on the Market!

...All Rockwood Turrets Discharge FogFOAM
Solid FOAM Stream — WaterFOG — Solid Water Stream

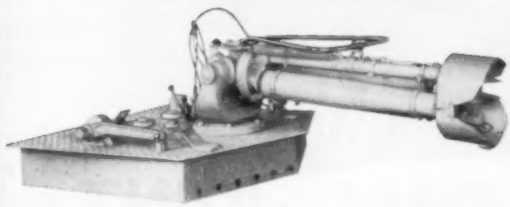
Extended Manual Control Type — Turret nozzles extend 10 to 20 feet above remote control station on deck or ground on standard units . . . greater remote extensions for special applications.



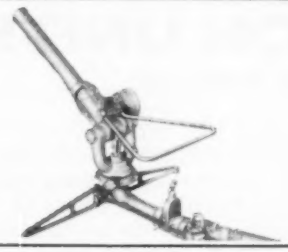
Direct Manual Control Type — Gives fire fighters "out-in-the-open" control from cab roof!



Remote Manual Control Type — Easily handled by man in driver's seat. Ideal for fast action!



Remote Hydraulic Control Type — Power-controlled from within the cab. Single and dual models. Widely used on air crash rescue fire-fighting trucks.



Portable Type — Off the truck and into action in seconds! Goes wherever a fire fighter can bring the proper hose line into action!

On the truck or on the ground, fire fighters can hit fires *harder* using ROCKWOOD Turrets! At airports and refineries . . . in municipalities and throughout industry . . . these advanced-design fire-fighting aids are constantly proving their ability to extinguish fires faster.

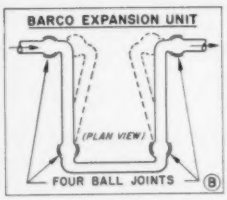
ROCKWOOD Turrets provide plenty of volume *and* versatility. What's more, all are easily adjustable on the fire line to meet changing fire conditions. Produced by the world's largest manufacturer of specialty Fire-Fighting Turrets, they're designed to give fire fighters an extra edge of efficiency on most types of fires. Get full details on the complete line of fire-fighting products. Write ROCKWOOD SPRINKLER COMPANY, Portable Fire Protection Division, 500 Harlow Street, Worcester 5, Massachusetts.

ROCKWOOD SPRINKLER COMPANY
A Division of the Gamewell Company
Engineers Water ... to Cut Fire Losses
Distributors in all principal cities.

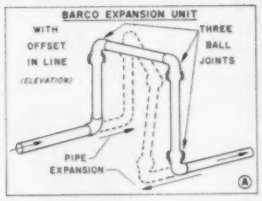
For more data on advertised products, use Readers' Service Cards, last page.

Handling Pipe Expansion in 1,300 ft. Asphalt Lines

PROBLEM—At this plant in Arkansas, asphalt at 500°F is pumped from refinery through approximately 1,300 feet of steam traced 6" insulated steel pipe. Heating of the piping causes a considerable increase in length. The problem of calculating movement and making proper allowance for this pipe expansion was complicated by the fact that the piping runs at various angles and elevations. *(See ANSWER below.)*



These schematic diagrams from Barco Bulletin 31A explain the accompanying photos.

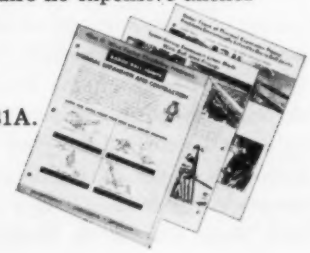


BALL JOINT EXPANSION UNITS

(NO REACTIVE FORCES)

ANSWER—Barco Ball Joints solved the "pipe expansion" problem SIMPLY, ECONOMICALLY, EFFECTIVELY. No complicated calculation of stresses was required—Barco Ball Joints (see arrows) provide *points of flexibility.* In offsets (A), three joints allow for expansion; or four joints (B) are used to form a minimum size expansion loop.

Rugged "Fire-Safe" Barco joints have no thin wall sections, no critical points of fatigue, no rubber seals. They develop no "end thrust"... *no reactive forces;* require no expensive anchoring. They are ideal for steam and all kinds of fluids, including asphalt. Choice of styles and sizes ½" to 16" to meet your requirements. SEND FOR BARCO BULLETIN 31A.



BARCO MANUFACTURING CO.
5426 Hough Street, Barrington, Illinois
In Canada: The Holden Co., Ltd., Montreal

Suppliers . . .

BALDWIN-LIMA-HAMILTON CORP. has elected **Robert O. Bullard** vice president and general manager, Electronics and Instrumentation Division, Waltham, Mass. Formerly general manager of the Power Tube Department, General Electric Co., Schenectady, N. Y., he has experience in management, electronics development and manufacture, and metallurgy. With General Electric since he graduated from college in 1930, Bullard has been a member of the company's top management for 15 years. He has 10 years of experience in electronics work.

Bullard

JONES & LAUGHLIN SUPPLY DIVISION has named **J. W. Crownover, Jr.,** store manager, Worland, Wyo., and **R. J. Farley** store manager, Edmonton, Alta. Crownover has been with the company since 1946, and Farley since 1956.

METALS DISINTEGRATING CO. has named **Frederic T. Cliffe, Jr.,** pigment sales supervisor, Eastern Sales Territory. For the past three years he has been in MD sales of aluminum and gold bronze pigments in Eastern New York.

BRADY ENGINE CO. has been named a distributor of Parker-Hannifin Corp.'s industrial hose and reusable fittings. Located in Houma, La., the firm says it will carry wide stocks.

U.S. STEEL CORP.'s Oil Well Supply Division has named **O. V. Coke** district engineer, machinery and equipment sales and service, Wichita, Kan. He has been with the firm in Oklahoma City since 1952.

U.S. INDUSTRIES, INC. has elected **Clarence B. Rex** vice president. He will continue as treasurer, a post he has held since early 1958. Rex has been with the company since 1955.

C. LEE COOK CO. has named **Charles J. Kremer, Jr.,** and **Richard W. Hoyt** vice presidents. Kremer, who joined the firm in 1927, will be in charge of engineering. Hoyt, with Cook since 1935, will manage the Airtomic Products Division.

WOLVERINE TUBE DIVISION has appointed **L. A. Brewer** manager of Strubing sales. Formerly a sales representative in the New York area, his new base of operation will be the administrative office, 17200 Southfield Road, Allen Park, Mich.

R. MACK GOBLE CO., Houston, has been appointed sales representative for Conoflow Corp., leading manufacturer of final

Progress in the "petro-chemical future" depends on the Engineering Specialist

Engineering, especially in the petro-chemical industry, is undergoing a metamorphosis of great significance . . . for as processes and applications become more complicated and definite, there emerges the demand for the qualified expert in the various phases of this complex industry — a real need for engineering specialists.

Western's recognition of its "petro-chemical future" — more than a dozen years ago — put the manufacture of Western heat exchangers under the critical scrutiny of specialists in the fields of design, thermal rating, metallurgy and mechanical engineering. The responsibilities entrusted to their care by our customers is testimony to the expertness of their work . . . and they merit your confidence, too.

WESTERN'S STAKE IN YOUR FUTURE

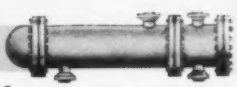
Upon the shoulders of the specialists—schooled, trained and experienced in specific phases of research, design, fabrication and operation of process equipment and methods — rests the responsibility of future development. Emphasizing the value of such specialization is the next of Western's "professional-advancement" messages, shown at right, now being carried in leading chemical and petroleum trade journals . . . available in more complete detail in pamphlet form, upon request.

One of a series appearing in OIL & GAS JOURNAL, CHEMICAL ENGINEERING, PETROLEUM REFINER, REFINING ENGINEER, CHEMICAL ENGINEERING PROGRESS.

serving the growth of the process industry

WESTERN

HEAT EXCHANGERS



WESTERN SUPPLY COMPANY

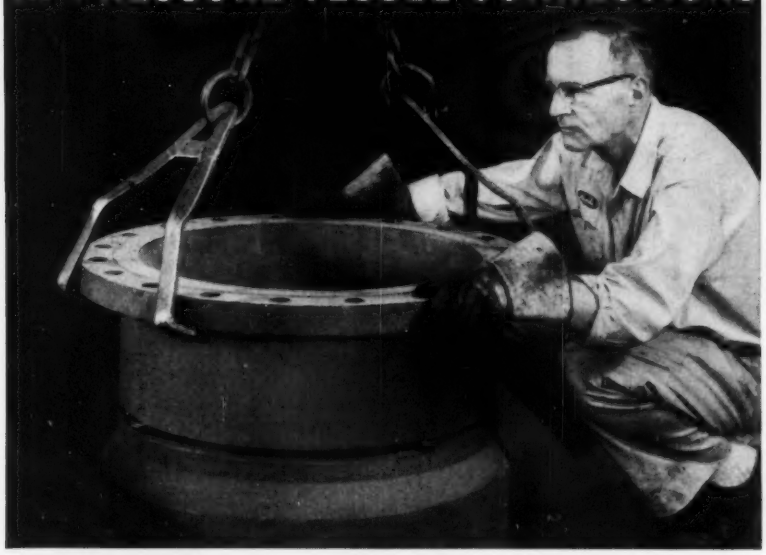
P.O. Box 1888 – Tulsa, Oklahoma

Trained Specialists Vitally Important In Process Engineering And Estimating . . .

The rapid, even meteoric development of the petro-chemical industry in the past decade has enhanced the role of importance played by engineering specialists with each step of its progress. Today, the engineer who is equipped with knowledge, study, training and experience in some specific phase of the processing cycle finds himself in an extremely favorable position and nowhere is this more obvious than in the realm of process engineering and estimating.

For more data on advertised products, use Readers' Service Cards, last page.

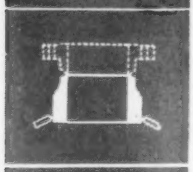
LENAPE OFFERS A NEW CONCEPT IN PRESSURE VESSEL CONNECTIONS



Now—by combining a Lenape ASA bolt flange which is a short seamless welding neck and your choice of three seamless bodies, you get optimum reinforcement, design flexibility and economy.

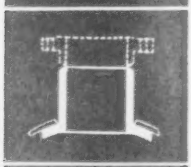
SPECIAL ASA BOLT FLANGE

Simple, low cost attachment, with easier alignment and orientation. You can choose different materials for body and flange, as well as length with unmatched economy in lengths over 12".



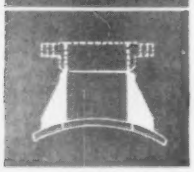
SEAMLESS CYLINDER EXTENSION

Superior to pipe or rolled plate. No seams. Built-in reinforcement. Choice of length and thickness.



TYPE C INTERNAL REINFORCING NOZZLE

Separate bolt flange makes more efficient internal reinforcement possible.



TYPE D EXTERNAL REINFORCING NOZZLE

External attachment with massive reinforcement.

All of these are available in 300 to 900 lb. ASA standards.

Full details and specifications are given in the new 96-page Lenape Catalog. Write for your copy.

LENAPE PRESSURE VESSEL CONNECTIONS

LENAPE HYDRAULIC PRESSING & FORGING CO.
DEPT. 106 WEST CHESTER, PA.
RED MAN PRODUCTS

Suppliers . . .

control elements. **J. Robert Simpson,** Conoflow's sales manager, said that the Goble firm will be exclusive representative for Conoflow in the Houston-Gulf Coast area.

AMERICAN BILTRITE RUBBBER CO., INC.'s Boston Woven Hose & Rubber Division has appointed **James M. Flounders** vice president in charge of research and development. A graduate of the University of Delaware, he attended Northwestern University Institute of Management, and is a member of Tau Beta Pi. He has been associated with the manufacture, development, and sales of industrial and consumer rubber products for more than 20 years. Starting in the Technical Department, Electric Hose and Rubber Co., he transferred to the Technical Department, B. F. Goodrich Rubber Co., where he became sales manager of all hose. Most recently, he was named director of new product development, B. F. Goodrich Industrial Products Co.

Flounders

THE YALE & TOWNE MANUFACTURING CO.'s Yale Materials Handling Division, Cincinnati Branch, has been purchased by Moon Equipment Co., Philadelphia. Moon will maintain Yale offices at 9880 Springfield Pike, Philadelphia.

THE PHILIP CAREY MANUFACTURING CO. has appointed **Robert J. Littin** merchandise manager for industrial insulation products. He will headquarter in the Cincinnati general offices. Littin graduated from the University of Toledo.

VULCAN CONTAINERS, INC. has named **Vern I. McCarthy, Jr.,** to the board of trustees of the School of Packaging Foundation, Michigan State University. The School is directed by **Dr. A. J. Panshin.**

CONSOLIDATED ELECTRODYNAMICS CORP. has elected **Jack E. Cressman** public relations manager. Before joining CEC in 1955 as public relations chief, he was financial editor, *Pasadena Independent,* and a United Press reporter.

LA SALLE STEEL CO. has named **Warren J. Trifiro** a sales representative, Southeastern Territory. A graduate of Boston College, he joined La Salle from Lewis-Shepard Products, Inc.

KIELEY & MUELLER CO. has appointed Continental Viking, Inc., as its Southwestern sales representative. The firm has offices and warehouses at 9426 Katy Road, Houston.

RAYTHEON CO. has elected **Charles F. Adams** chairman of the board and **Richard E. Krafve** president. Adams is presi-

For more data on advertised products, use Readers' Service Cards, last page.

accuracy

ASHCROFT DURAGAUGES measure pressure with precise accuracy no matter how severe the conditions of service

Ashcroft Duragauges are available in pressure ranges from 15 psi (or vacuum) minimum to 100,000 psi. Dial sizes: 4½" through 12".

sustained

The Bourdon tube in Ashcroft Duragauges is manufactured to precision standards of flexibility and mono-linked to the rotary movement. When pressure flexes the tube, the gauge pointer is always positively positioned, because it is mounted on the geared center shaft of the movement. Sustained high accuracy and long life are assured.

Choose your Ashcroft Duragauges made of components best suited to your needs. Eight Bourdon tube materials are available. Movement of stainless steel with nylon bearings and pinion gear for longest wear. Case materials: special aluminum alloy or tough phenol plastic.

The unique "Maxisafe®" Duragauge provides absolute protection to the viewer, plus easy and quick access to the mechanism. Your industrial supply distributor will help you select the best combination of components for your Ashcroft Gauge requirements. Phone him today or write for Catalog 300B.

MANNING MAXWELL & MOORE INC. TRADE MARK

ASHCROFT PRESSURE GAUGES

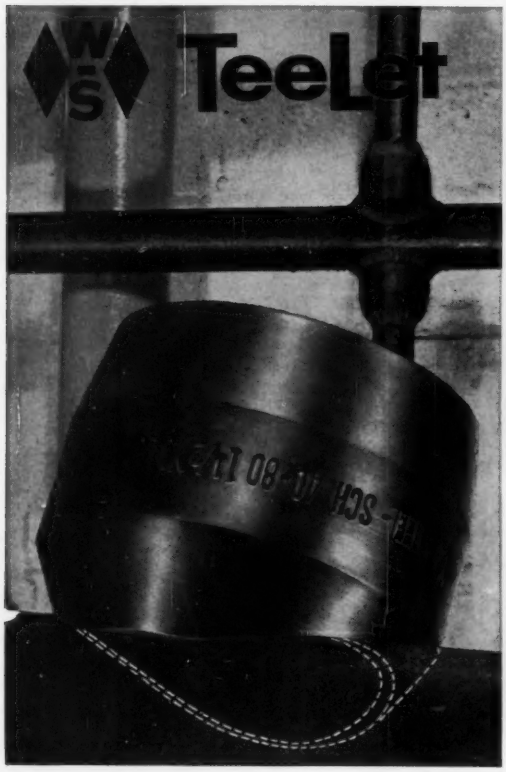
A product of

MANNING, MAXWELL & MOORE, INC.

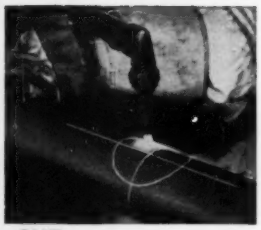
Gauge and Instrument Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.

FOR ⅛ TO 1½ INCH BRANCH CONNECTIONS



MARK



CUT

WELD

NEW W-S TeeLet SLASHES TEE COSTS 50% OR MORE!

The new W-S TeeLet replaces conventional Tees of cast or malleable iron, welded or forged steel . . . requires fewer stock sizes. Available in sizes from ⅛ to 1½" IPS, TeeLets are fully machined from forging quality solid steel bars and adapt to run-pipe sizes to 36". They require no additional joint strength calculations for any ASTM A-53 or A-106 Grade B run-pipe of Schedule 40 or 80.

What about cost? A size-by-size comparison with conventional Tees shows TeeLets average less than 50 per cent of the cost you now pay. A W-S TeeLet, with screwed, socket-weld or butt-weld ends, requires no shaping, fitting, beveling or extra alignment. You can connect to the run-pipe at any point. Short heights mean easy inspection of the attachment weld or back-weld, if desired.

A W-S TeeLet costs less to buy, less to install than anything you can buy or make. For complete information, prices, and names of distributors, write: *Forge and Fittings Division, H. K. Porter Company, Inc., Box 95, Roselle, N. J.*

FORGE AND PORTER FITTINGS DIVISION

H.K. PORTER COMPANY, INC.

PORTER SERVES INDUSTRY with steel, rubber and friction products, asbestos textiles, high voltage electrical equipment, electrical wire and cable, wiring systems, motors, fans, blowers, specialty alloys, paints, refractories, tools, forgings and pipe fittings, roll formings and stampings, wire rope and strand.

Suppliers . . .

dent of the firm and Krafve has been group vice president, commercial, since April 1959.

PANELLIT SERVICE CORP. has appointed **Louis G. Good** vice president in charge of operations. His new responsibility is the complete technical and business supervision of PSC's instrumentation and control engineering organization. After graduating from Virginia Polytechnic Institute, he worked for Celanese Corp. of America, North Carolina Pulp Co., and U.S. Army Engineering Corps. He joined PSC in 1953. Good is a member of ASME, ISA, and Technical Association of the Pulp and Paper Industry. At present, he is Director of the Pulp and Paper Division, Industries Department, ISA.

Good

OPW-JORDAN CORP. has appointed **G. A. Groh** sales engineer, Cincinnati. A graduate of Xavier University, he formerly represented a local manufacturers' agency. He will supervise sales in several territories.

THE CARPENTER STEEL CO.'s Alloy Tube Division has named **Richard F. Henley** territorial manager, Cincinnati area. He was previously with Industry Export Service, Inc., and Monsanto Chemical Co.'s Overseas Division.

JOHN WOOD CO.'s Bennett Pump Division has named **John Klier** sales representative, Chicago District. He has a seven-year background in equipment sales in the Chicago area. Klier will assist in management and distribution.

DELTA TANK MANUFACTURING CO.'s Oilfield Equipment Division has named **E. G. Murphy** Western Region sales manager, Houston. He has been manager of several large manufacturing firms for the past 35 years.

MINNEAPOLIS-HONEYWELL REGULATOR CO.'s Industrial Systems Division has named **Robert G. Butterwick** advertising and sales promotion manager. A journalism graduate of Stanford University, he joined Honeywell in 1951.

PUROLATOR PRODUCTS, INC. has completed new research facilities housed in a $500,000 building with more than 13,000 feet of floor space, at Rahway, N. J. It will accommodate pure research and new product development.

CONSOLIDATED ELECTRODYNAMICS CORP. has appointed **Raymond V. Meck** controller. Formerly manager of accounting services, he has been with the firm five years. He graduated from Northwestern University.

for superior jet fuels...

MOLEX

TRADEMARK

THE PROCESS THAT PRODUCES A NEW KIND OF JET FUEL OFFERING BIG AND EXCITING POSSIBILITIES

Jet flight is here to stay. But jet *fuels*, like yesterday's gasolines, will be replaced by better, more improved types . . . the kind made possible by Molex.

A unique, new *continuous* process developed by UOP, Molex removes up to 99% of the normal paraffins in gasoline mixtures, produces a superior jet fuel with these exclusive advantages:

Higher heating value per pound
. . . for greater range or payload.

Lower luminosity
. . . for lower metal temperatures, less carbon deposit, lower overhaul expense.

Less smoke in engine exhaust
. . . for more effective smog control.

High thermal stability
. . . eliminates heat exchanger fouling.

'62 COULD BE THE YEAR FOR YOU!
The consensus of informed opinion is that 1962 will require a substantial increase in process capacity . . . NOW is the time to start your planning! Ask us about a preliminary proposal, no obligation!

UOP® UNIVERSAL OIL PRODUCTS COMPANY

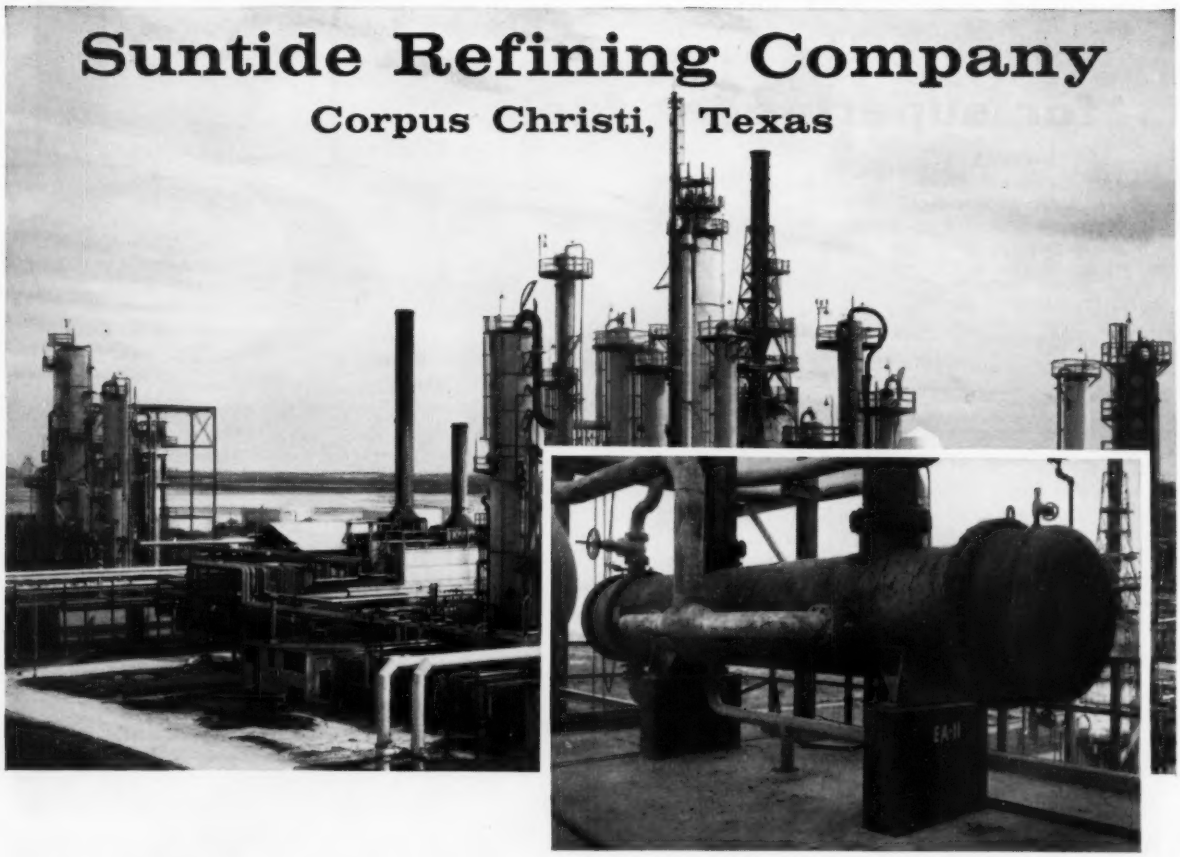
30 Algonquin Road
Des Plaines, Illinois, U.S.A.

WHERE RESEARCH TODAY
MEANS PROGRESS TOMORROW

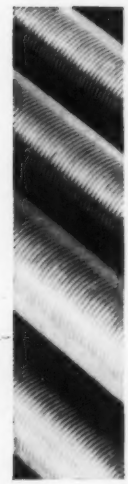
For more data on advertised products, use Readers' Service Cards, last page.

Suntide Refining Company

Corpus Christi, Texas



Estimates 20% more capacity from new heat exchanger without increasing size of unit...



REASON:

This Unit made by ENGINEERS & FABRICATORS, INC., HOUSTON, TEXAS is equipped with REVERE INTEGRAL FINNED TUBES

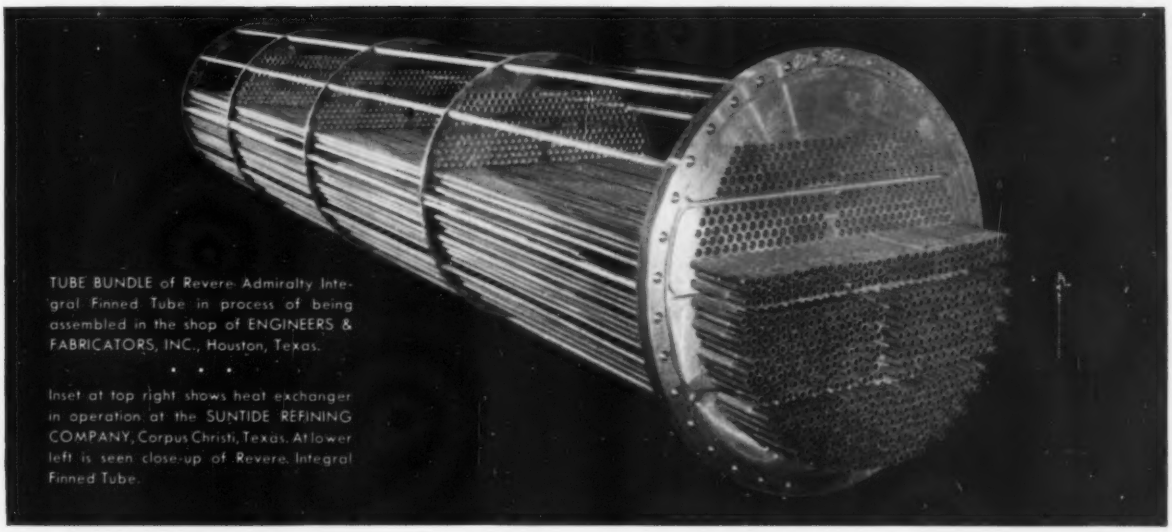
For more data on advertised products, use Readers' Service Cards, last page.

Originally the heat exchanger used by Suntide in producing cracking stock, was equipped with plain surface condenser tubes. After it had been in operation for some time, the process engineers at Suntide found that increased capacity was needed. But how could the capacity of the unit be increased without increasing its size or sacrificing its efficiency?

The purchasing and process departments of Suntide, in conjunction with Revere's Technical Advisory Service, studied the problem from every angle. The result was the specifying of 12,736 feet of ¾" OD Revere Admiralty Integral Finned Condenser Tubes . . . the same number of linear feet as originally used. It is estimated that through the increased efficiency of the unit, a 20% increase in capacity will be brought about by the use of Revere Integral Finned Tube.

To find the alloy or type of tube best suited to meet a specific set of operating conditions, Revere offers the help of its Research Department, made available through Revere Technical Advisory Service.

In addition to Integral Finned Tube, Revere also makes Bimetal Tube, Instrumentation Tube, Condenser Tubes in Cupro-Nickel, Aluminum Brass, Admiralty, Arsenical Copper, and other alloys; small and large plates and tube sheets in Cupro-Nickel, Copper, Herculoy, Muntz Metal, Naval Brass and Admiralty; as well as Aluminum Tube, Sheet and Extrusions.



TUBE BUNDLE of Revere Admiralty Integral Finned Tube in process of being assembled in the shop of ENGINEERS & FABRICATORS, INC., Houston, Texas.

• • •

Inset at top right shows heat exchanger in operation at the SUNTIDE REFINING COMPANY, Corpus Christi, Texas. At lower left is seen close-up of Revere Integral Finned Tube.

REVERE

COPPER AND BRASS INCORPORATED

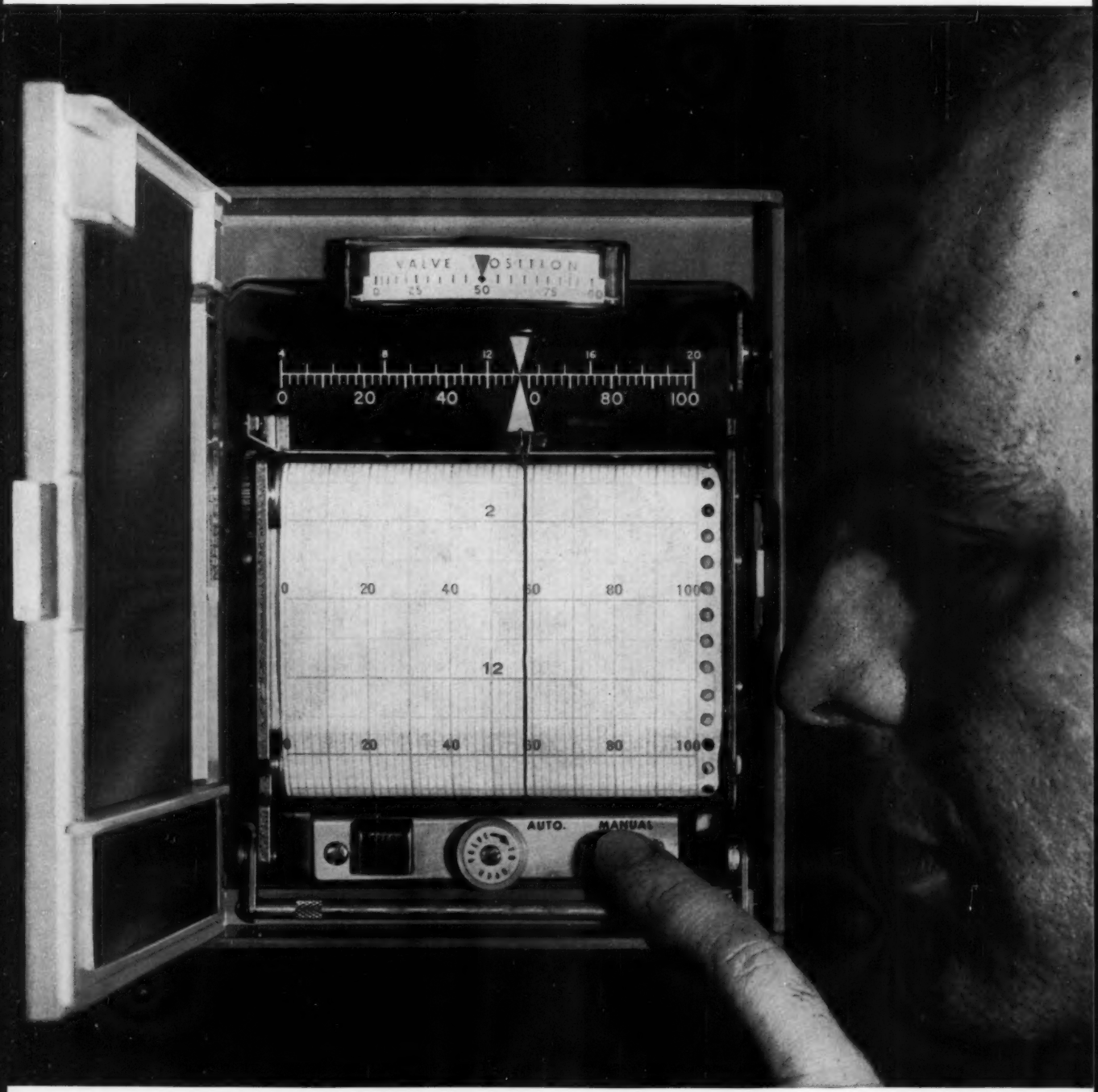
Founded by Paul Revere in 1801

230 Park Avenue, New York 17, N. Y.

Mills: Rome, N. Y.; Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles, Riverside and Santa Ana, Calif.; New Bedford, Mass.; Brooklyn, N. Y.; Newport, Ark.; Fort Calhoun, Neb. Sales Offices in Principal Cities, Distributors Everywhere.

For more data on advertised products, use Readers' Service Cards, last page.

New *ElectriK Tel-O-Set*... needs in a single compact



everything an operator control station

This Honeywell electric control station meets all of your requirements for operator convenience.

One compact case houses *every* function the operator needs to supervise a control loop: indication of process variable and set point on the same scale; the controls needed to switch from automatic to manual; controls for manual control; and indication of valve position.

The *ElectriK Tel-O-Set* control station assures easier bumpless transfer than ever before available because there's no need to "line up" or "match" pointers. A null balance indicator eliminates guesswork, and the transfer doesn't have to be hurried since the valve remains under control during the transfer.

You can also order the controller with the proportional band, rate, and reset adjustments on the front of the panel conveniently located below the control station, or at the rear of the panel.

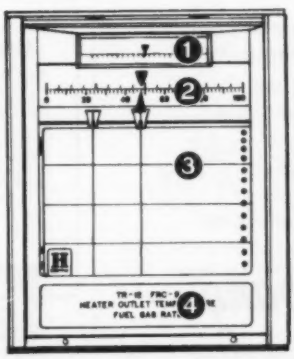
These are just a few of the features that make the new *ElectriK Tel-O-Set* control system an outstanding value. Your Honeywell engineer can give you complete details. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Fall River, Massachusetts.

75th YEAR
PIONEERING THE FUTURE

Honeywell

H HONEYWELL *First in Control* SINCE 1885

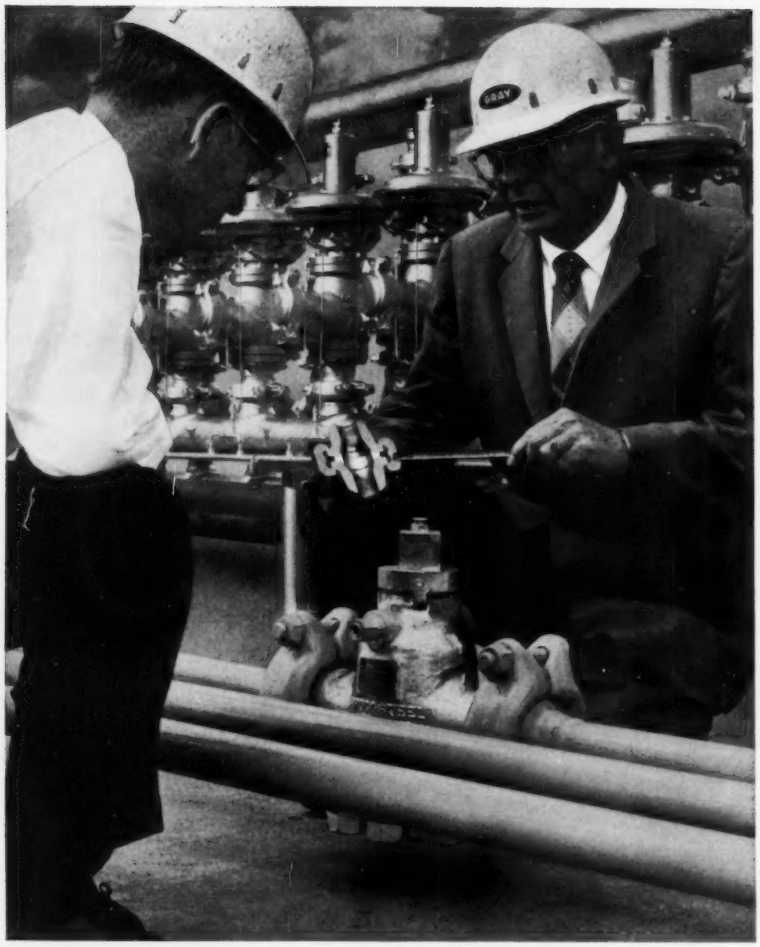


1. Valve position indicator continuously indicates controller output when on automatic control.

2. Set point index is conveniently located on same scale as process-variable pointer; you can see from a distance any deviation of variable from set point.

3. Rectilinear 4-inch calibrated chart is easy to read. At standard chart speed, four hours of recording is always visible. Unit has daily chart tear off or 30-day rewind. Both recorder and control station take the same 5½" x 6" panel cutout.

4. You get bumpless switching from automatic to manual control because you don't have to match pointers. In the balance position, the valve position indicator is part of a null circuit that compares controller output and manual output. When indicator reads 50%, both outputs are perfectly matched.



GRAYLOC® Seal: Leak-proof at any pressure

Leak-proof quality of GRAYLOC Seals in piping applications has been use-proved from full vacuum to 30,000 psi and test-proved up to 150,000 psi. Holding at any pressure makes GRAYLOC practical in applications requiring positive leak-proof connections.

The GRAYLOC Seal is available in two-bolt clamp-type or conventional flange connections. Its simple steel design features a rigid rib with lips on either side tapering slightly less than the mating hub to form a line seal at the touchpoint. As the connection is tightened, the lips deflect to form a surface seal. GRAYLOC connections provide a permanent steel seal that can be made up repeatedly, operating to pressure without seal ring replacement. Stock connections available from ½" to 30" and on special order in corrosion-resistant metals.

If you want to know more about how GRAYLOC Connections can permanently solve your leakage problems, write for the new GRAYLOC CATALOG on your company letterhead.

GRAY Tool Company

GRAYLOC SALES DIVISION

P. O. BOX 2291 HOUSTON 1, TEXAS Riverside 7-1240 05

Suppliers . . .

THE C. B. THAW COMPANY, INC., Philadelphia, has named **Charles P. Seabo** to assist in the engineering and selling of heat exchange equipment manufactured by Brown Fintube Co. From 1955-60, Seabo was with Mobil Oil Co., Paulsboro, N. J., in various capacities as project, construction and maintenance engineer. He will supervise the Philadelphia-area sales of double-pipe finned heat exchangers, tank heaters, tank suction and line heaters, indirect fired heaters, and other heating and cooling equipment.

Seabo

BORG-WARNER CORP.'s Ingersoll Products Division has acquired Elgin Mtalformers Corp., Elgin, Ill. Elgin is a supplier of metal modular-type enclosure to the electronics and communications industries.

THE INTERNATIONAL NICKEL CO.'s Huntington Alloy Products Division has named **L. E. Grubb** vice president, sales, and **E. M. Kline** vice president, operations. **John A. Marsh** is the division's new president.

SOUTHWESTERN INDUSTRIAL ELECTRONICS CO. has named **W. A. Laukaitis** Eastern Region marketing manager. He was formerly manager of W. L. Maxon Corp.'s Washington office.

H. R. GILBERT CO., New Orleans, has been appointed sales representative for The Hays Corp., Michigan City, Ind. **H. R. Gilbert,** who heads the Louisiana company, has been active for some time in instrumentation and sales.

JONES & LAUGHLIN STEEL CORP. has named **Charles M. Beeghly** president. He has been an executive vice president since April 1958, and a director since October 1957. He has been in the steel industry 25 years.

REFRACTORY HAYDITE

Makes Higher Heat Resistant Concrete

Haydite aggregate used with Lumnite cement produces refractory concrete suitable for sustained temperatures up to 1800-2000° F., which makes it excellent for tubular heaters, ducts, flues, stacks and catalytic crackers. Weighing from 30 to 40 per cent less than ordinary aggregate concrete, Haydite is exceedingly strong. It has excellent insulating properties and withstands pressures of up to 1130 pounds per square inch. Write today for free folder and complete information about Carter-Waters Refractory Haydite.

We sell direct to you.

CONSTRUCTION MATERIALS

CARTER-WATERS

KANSAS CITY MISSOURI

2440 Pennway Phone GRand 1-2570

Let Du Pont help make your handling and blending of TEL safer, easier, faster

Over the years Du Pont engineers have made a number of worth-while contributions directed toward the more satisfactory handling of tetraethyl lead at the refinery.

The most recent is a new blending plant design, some features of which can be incorporated advantageously by you in older plants. Among the advantages of the new design are a smaller building, the elimination of windows and weigh-tank well and the more economical location of valves at the end of the weigh-tank instead of alongside.

The three-inch unloading line, which can cut unloading time in half, is another Du Pont innovation. So is the siphon starter, which reduces problems caused by siphon breaks in the vacuum system. The Metal-Flex hose requires only one man to attach unloading line to tank car dome, eliminates troublesome leaks and repacking of swing joints, and makes for safer operation.

If you are not familiar with some of the above developments or have other TEL matters you would like to discuss, get in touch with your Du Pont representative soon.

DU PONT

Better Things for Better Living
. . . through Chemistry

Tetraethyl Lead
and other
Petroleum Additives

INTERCHANGEABLE
UNION
ENDS
FULL
PORT
OPENING
BETTER
BALL VALVE

Versatile Cooper Ball Valves throttle like globe valves; handle slurries like diaphragm valves; control flow with the positive on-off operation of gate valves. Full port openings — straight through flow pattern — no turbulence. Interchangeable union ends for maximum versatility in any of the wide variety of end connections available. Valves go "on stream" in minutes. No other ball valves give you these plus features which guarantee maintenance-free operation and *eliminate costly down time.* Write for Bulletin BVF.

COOPER ALLOY
Corporation • Hillside, New Jersey

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

DELTA TANK MANUFACTURING CO., INC.'s Oilfield Equipment Division has named **Floyd Hentschel** district manager, Baton Rouge, La., with headquarters in Shreveport. A veteran of 24 years in the petroleum equipment business, he had served in a managerial capacity with other major manufacturers of petroleum equipment before joining Delta. Hentschel is a member of API and the Petroleum Club of Shreveport.

Hentschel

THE INTERNATIONAL NICKEL CO. OF CANADA, LTD. has elected **Richard A. Cabell, Albert P. Gagnebin, Ralph H. Waddington** and **James Parlee** vice presidents. **Paul Queneau** becomes technical assistant to the president.

BORG-WARNER CORP. has purchased a 25.4-percent interest in Ralph McKay, Ltd., Australian implement parts manufacturer. Under the agreement, a total of 640,000 shares of McKay stock will go to Borg. Warner.

THERMO ELECTRIC CO. has opened a new factory office for Southern California. The office, which will market temperature measuring systems, thermocouples and accessories, is at 19458 Ventura Blvd., Tarzana, Calif.

DRAVO CORP. has opened a modern, highly automated plant for the manufacture of welded industrial grating, in Pittsburgh. The firm has been sales distributor of grating and stair treads for 30 years.

ALCO PRODUCTS, INC. has opened executive and sales offices at 530 Fifth Ave., New York. The move was made to provide a more central location in the metropolitan area, according to the company.

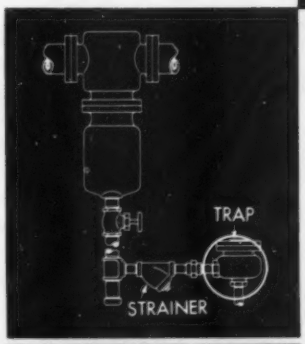
FLORIDIN CO. recently observed its 50th anniversary with a week-long celebration in Tallahassee, Fla., the firm's headquarters city. The firm was founded by a group of oil men in Warren, Pa., in 1910.

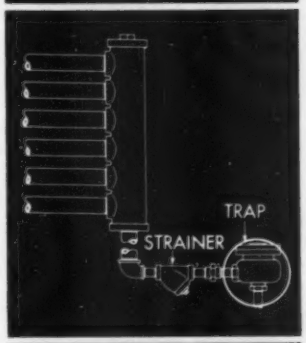
DORR-OLIVER, INC. has named **Oscar W. Johnson** manager of the new Petroleum and Petrochemical Division, Industrial Sales Area. With the company three years, he was most recently staff assistant to the general sales manager.

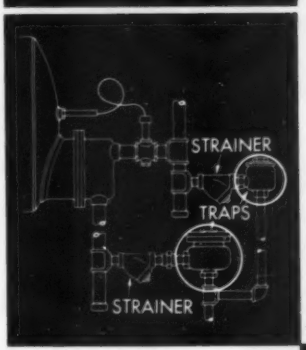
VICTAULIC CO. OF AMERICA has appointed **Albert C. Moeser** sales representative in the Southeastern area. He will cover Alabama, Georgia, Florida, Mississippi and South Carolina.

RAYSBESTOS-MANHATTEN, INC.'s Manhatten Rubber Division reports the death

sure . . . steam traps are a mere fraction of total steam equipment cost, but . . .







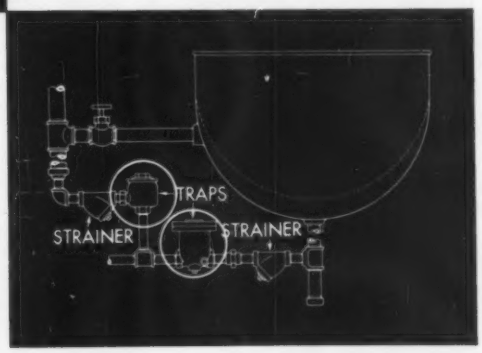
. . . what about your TOTAL thermal efficiency?

When you aren't getting top efficiency from your equipment . . . when leaking, dribbling steam waste lessens its full usefulness . . . when air or other non-condensables cause trouble . . . where do you look? Your steam traps! That's why it's mighty important that they (1) fully discharge condensate, air and other non-condensables promptly and (2) give long trouble-free service. Nicholson traps meet the first requirement because they operate on a *true balanced pressure* principle . . . and the second, because they only have one moving part, thus reducing the possibility of down-time. Other advantages are positive shut-off . . . high capacity . . . rigid pretesting.

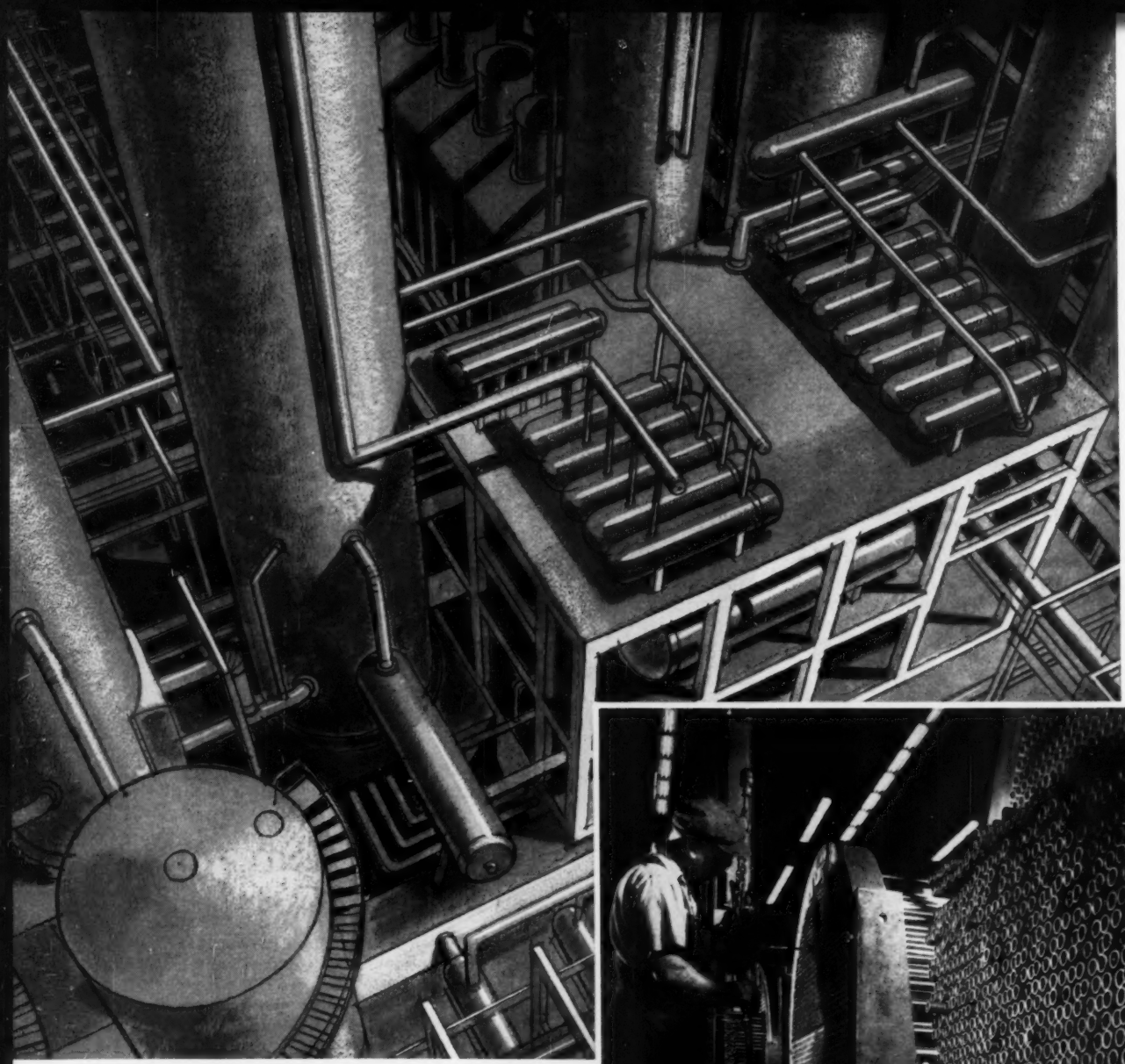
Let's tell you more . . .

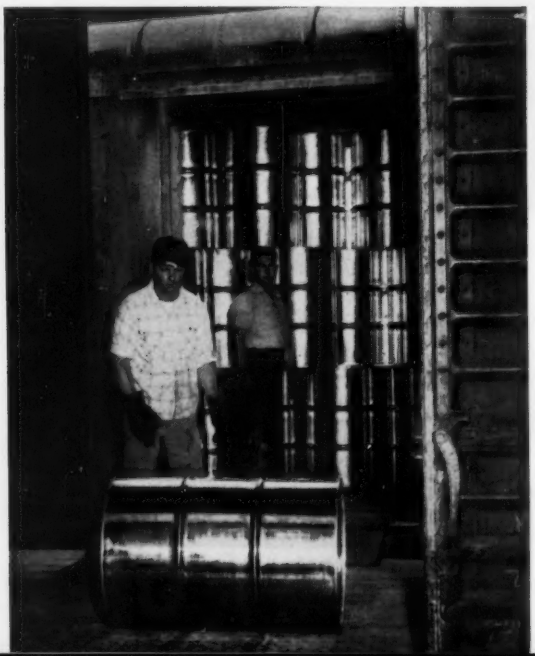
Write for Catalog

W. H. NICHOLSON and COMPANY
12 Oregon St., Wilkes-Barre, Pa.



For more data on advertised products, use Readers' Service Cards, last page.





C F Braun & Co, fabricators of heat exchangers for the gigantic gas plant on the huge King Ranch, reported rolling in operations with ELECTRUNITE are excellent. With ELECTRUNITE, every tube is truly round, uniform in wall thickness, strength, ductility, concentricity, diameter, and other physical properties to meet critical performance specifications. Photo courtesy C F Braun & Company, Engineers and Constructors.

REPUBLIC STEEL DRUMS PROTECT THEIR CONTENTS! Rugged on the outside, chemically clean on the inside, for protection of contents under all conditions of service. Available in a wide range of types and sizes, in both light and heavy gage classifications—hot dip galvanized, hot dip tinned, stainless steel, rolled carbon steel—depending on specifications and service. Write for literature.

On Stream...WITH REPUBLIC

REPUBLIC ELECTRUNITE HEAT EXCHANGER TUBING

Ready to come on stream—Humble Oil & Refining Company's $70 million natural gas processing project, located on the huge King Ranch, Kleberg County, Kingsville, Texas.

The project was engineered and constructed by Humble Oil & Refining Company, and Hudson Engineering Corporation, Houston. C F Braun & Company, Alhambra, California, were heat exchanger fabricators.

More than a half million feet of Republic ELECTRUNITE, ¾" O.D. x 16 gage in 20-foot lengths, were used in the construction of the heat exchangers and condensers. ELECTRUNITE was selected because it surpassed the severe requirements of ASTM Specification A-214.

Produced from highest quality flat-rolled open-hearth steel in Republic's own mills—ELECTRUNITE is ELECTRically-UNITEd under pressure without additional foreign or extra metal. The tube wall is uniform in thickness, diameter, and ductility.

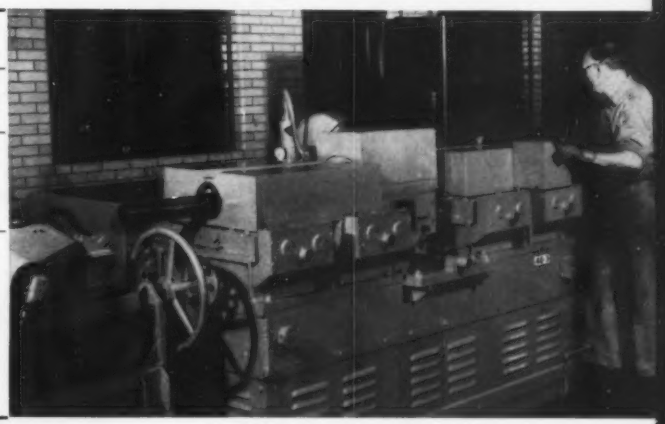
When the ultimate in non-destructive testing is desirable or required, Republic recommends FARROWTEST as an alternative to other types of testing. FARROWTEST is Republic's exclusive eddy-current test that probes for and detects defects so minute they pass other less positive tests. Tube quality is measured for you. See table.

Investigate the advantages of FARROWTESTED ELECTRUNITE for your boiler, heat exchanger, condenser, or evaporator applications. Call your Republic representative. Or, write direct.

FARROWTEST REJECT TABLE

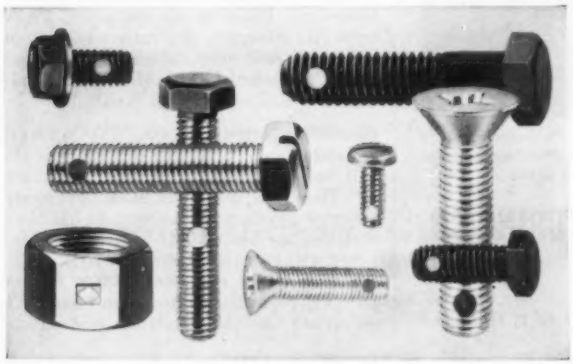
Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.



FARROWTEST—quality measured for you. Not a laboratory theory, not a mere inspection tool, but an exclusive production test that detects and rejects tubing containing defects of critical size. FARROWTEST is offered as an alternative to other less positive tests in accordance with the table, above, at no extra cost.

REPUBLIC NYLOK SELF-LOCKING FASTENERS provide a single-unit answer to vibration, shock, tension. A permanent nylon insert forces mating threads together for maximum holding power in any position. The relatively inert nylon resists age, moisture—is unaffected by temperatures from 250°F to —400°F. Its natural resiliency permits easy adjustment and repeated use. Send coupon for literature.



REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
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Please send more information on the following products:

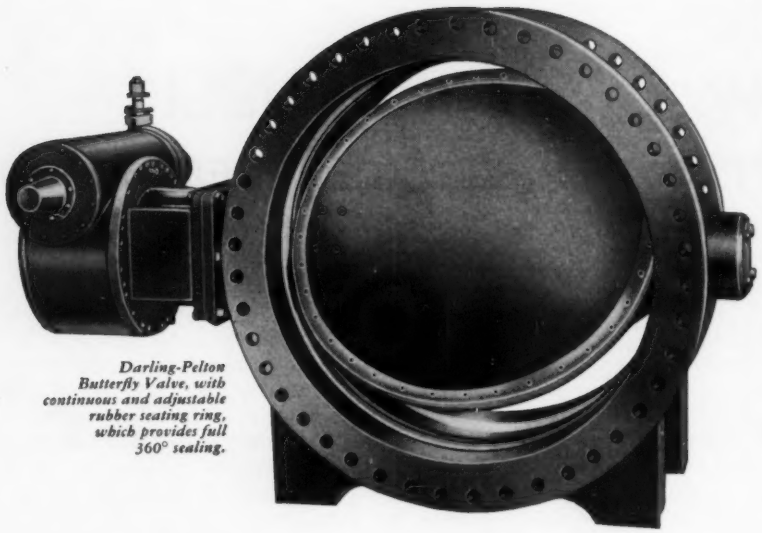
☐ Republic ELECTRUNITE® Heat Exchanger Tubing
☐ Carbon ☐ Stainless Steel ☐ FARROWTEST® Brochure
☐ Republic Steel Drums ☐ NYLOK® Fasteners

Name_____ Title_____

Firm_____

Address_____

City_____ Zone____ State_____



Darling-Pelton Butterfly Valve, with continuous and adjustable rubber seating ring, which provides full 360° sealing.

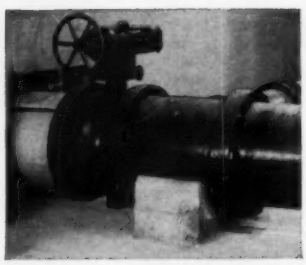
Surer sealing...easier maintenance

with **DARLING-PELTON BUTTERFLY VALVES**

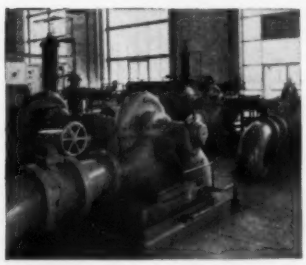
Darling-Pelton Rubber Seated Butterfly Valves are designed to give bubble-tight shut-off, easy operation and trouble-free service throughout the life of the valve. The sealing member is a continuous resilient ring displaced from the operating shaft... and fully adjustable to give bubble-tight closure around the circumference of the disc.

These high-performance valves are designed in accordance with A.W.W.A. specifications...for hydrostatic operating pressures up to 125 psi and velocities up to 16 feet per second. In addition to water service, they have been successfully used on vacuum, gas and chemical service.

To get *all* the facts, write us for Bulletin No. 5904.



Close-up view of installation in large municipal water plant.



View of Darling-Pelton Butterfly Valves installed in Pittsburgh's new filtration plant.

DARLING VALVE & MANUFACTURING CO.

Williamsport 31, Pa.

Manufactured in Canada by Canada Valve & Hydrant Co., Ltd., Brantford 7, Ontario

Suppliers . . .

of **Ralph A. McKinney,** 90, retired sales executive. He had joined the company in 1911 as a salesman, and later became Pittsburgh Branch manager.

CHEMETRON CORP.'s Tube Turns Division has named **Lincoln D. Hall** manager, Midwest District, Kansas City. He is in charge of sales in Colorado, Kansas, Missouri, Nebraska, North and South Dakota and Wyoming and portions of Illinois, Iowa and Montana. Hall, who had experience in construction, petroleum and industrial equipment industries, joined Tube Turns in 1951. He was Tulsa District manager before moving to the division's headquarters in 1955 as assistant sales manager supervising Western region operations.

Hall

GENERAL ANILINE & FILM CORP.'s Dyestuff and Chemical Division recently honored **J. Robert Bonnar** for his 25 years of company service. Bonnar was honored at a New York luncheon April 15.

CELANESE CHEMICAL CO. has named **Harry B. Bartley, Jr.,** field sales manager. He will direct activities of the field sales force and coordinate its work with other departments of the company.

ALLIED CHEMICAL CORP.'s Solvay Process Division has named **M. James Campbell** assistant director of development. Holder of a chemical engineering degree from Lehigh University, he has been with Solvay since 1939.

HOOKER CHEMICALS, LTD. has elected **Thomas F. Willers** president. He is also a vice president of Hooker Chemical Corp. where he is in charge of four divisions and corporate engineering.

THE COOPER-BESSEMER CORP. has appointed **Don B. Bramley** sales engineer St. Louis Branch. A mechanical engineering graduate of Brown University, Bramley will sell gas, diesel and gas-diesel engines.

GENERAL ANILINE & FILM CORP.'s Antara Chemicals Division has appointed **Frederick W. Morgart, Jr.,** sales engineer in charge of field sales, Minneapolis, Minn. He is a University of Minnesota graduate.

DEARBORN CHEMICAL CO. has named **Samuel Kruty** production manager. He will head manufacturing operations for all Dearborn product lines. Formerly assistant production manager, he has been with the firm since 1951.

THE NEW YORK AIR BRAKE CO.'s Aurora Pump Division has named **John Sharp III** supervisor of the electronic tabulating

For more data on advertised products, use Readers' Service Cards, last page.

New Process

* GUARANTEES

Lowest Product Recovery Cost
Shortest Unit Payout Time

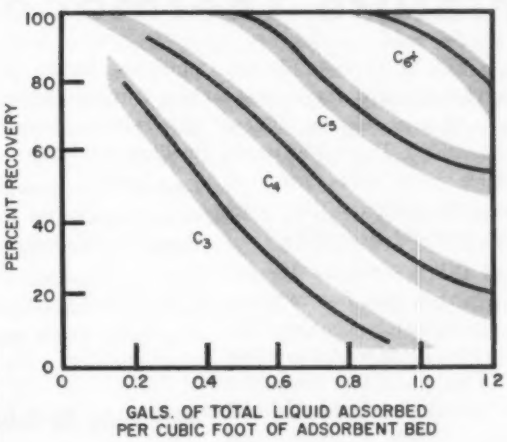
The Adsorption Process

DELTA DRYEX GASOLINE PLANT

The most economical commercial gasoline, butane and propane recovery process ever designed.

* Delta quotes a turnkey onstream installation with guaranteed recoveries.

- **A new concept for natural gasoline, butane and propane recovery.**
- **Recovers *both* natural gasoline and NGAA specification butane and propane.**
- **You get more product at a much lower cost (half in many cases) than any other commercial process.**
- **You are assured of shortest unit payout time.**
- **Dryex adsorption gasoline plants are complete including fractionation and refrigeration equipment which yield NGAA specification products.**



Dryex gasoline plants open a new realm of profit possibilities. Even those gas streams considered for other processes in the past and eliminated as economically impractical should be reviewed for a Dryex gasoline plant application.

LET DELTA ANALYZE YOUR GAS STREAM TO DETERMINE THE VALUE OF DRYEX TO YOU

Patent No. 2,880,818 dated April 7, 1959

For Brochure and Complete Information, Write:

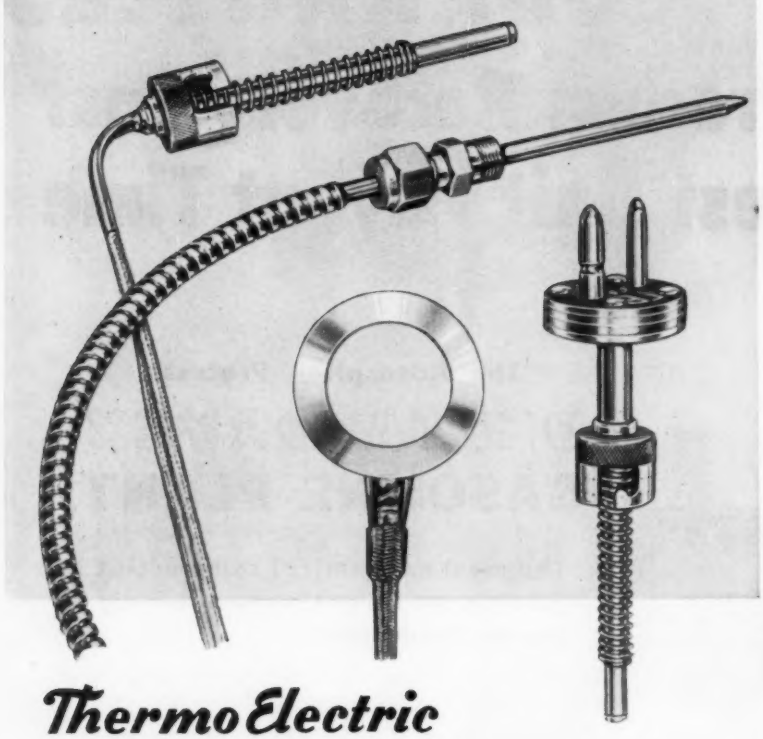
DELTA

DELTA TANK MANUFACTURING CO., INC.

P. O. BOX 1469 • BATON ROUGE, LA. • TEL. Dickens 3-5701

For more data on advertised products, use Readers' Service Cards, last page.

Peak Performance—
economy on the job!



Thermo Electric
Miniature Thermocouples

You can obtain a Thermo Electric Miniature Thermocouple for peak performance and economy in almost every application! Those illustrated are available in a wide variety of sizes, standard thermocouple materials, adapt to many applications.

Protected thermocouples are extremely sensitive, give fast response to minute temperature changes. The measuring junction is welded or silver soldered to the tip of the thin-walled "Ceramo" metal sheath. Ideally used in corrosive liquids or gasses—and many pressure applications. For quick-coupling versatility, the spring-loaded bayonet-lock thermocouple is tops! You can use one "couple" at various depths with different adapters. With spring-loading, tip contact is always maintained. The bayonet type is highly sensitive, fast responding, for use in pump and engine cylinder heads, turbine housings, pipes, electric motors, generators, plastic extruders and molding machines.

Gasket Thermocouples measure surface temperatures in all sorts of stationary or moving machinery.

T.E. also produces stagnation, exposed junction and shielded thermocouples for use in air, gas or vaporous atmospheres.

write today for Bulletin 1256-19

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

Suppliers . . .

equipment. For the past eight years he had been with the company's Hydreco Division, Kalamazoo, Mich.

U.S. INDUSTRIES, INC.'s Clearing Division has named **John R. Bartizal** president. He returns to the division after an absence of about six years. Previously, he had been with the company for 10 years through 1954, latterly as a director and executive vice president. When Clearing Division was acquired by U. S. Industries in 1954, Bartizal resigned to become chairman of the board and president of Benjamin Electric Manufacturing Co., Des Plaines, Ill., a position he held until December 1958. He has more recently been president of Schoolco, Inc.

Bartizal

FULLER CO.'s Dracco Division has named **Robert T. Pring** manager, dust collector sales. A registered professional engineer, he previously spent 10 years as technical director for a major dust collector manufacturer.

THE MUSGROVE SPECIALTY CO., Houston, has been appointed representative for UDELL, Inc.'s line of chemical injectors and pumping equipment. Musgrove will install and service pumps and injectors, and design and install corrosion control systems.

THE CARPENTER STEEL CO.'s Alloy Tube Division has appointed **Robert E. Hilleman** territorial manager, St. Louis, Mo., branch warehouse. For about three years he has been with Keuffel & Esser Co.'s St. Louis Branch.

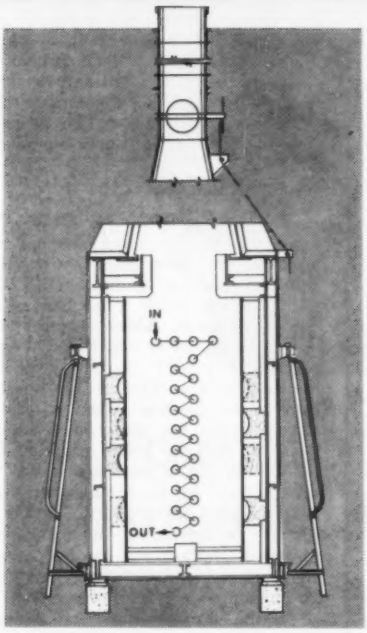
INGERSOLL-RAND CO. has named **Joseph A. Wiendl** general manager of sales. Previously assistant general manager of sales, he joined Ingersoll-Rand in 1941 after graduation from Montana School of Mines.

CLARK BROTHERS CO. has named **William A. Roever** manager, Dallas District office. He will be responsible for the sale of engines, compressors and gas turbines in Central Texas and lower New Mexico.

BRIDGEPORT BRASS CO. has named **Newell W. Mitchell** corrosion-problem consultant in its heat exchanger activities, Technical Services Department, Sales Division. Mitchell was with Chase Brass & Copper Co. 20 years.

CLARK BROTHERS CO. has reported the death of **Herman W. Shubring,** its marketing consultant. He had been with Clark for nine years, and before that was with Ford, Bacon & Davis, Inc., and Northern Natural Gas Co.

Save TIME AND MONEY AT THE JOB SITE *with* SELAS PREFABRICATION



Selas prefabrication means much more than the generally-accepted definition: it means shop-assembly! Shop-assembled Selas Gradiation® tubular heaters . . both vertical and horizontal . . are *complete* when they are shipped out. Burners, brickwork, arch tiles are in place; manifold piping is attached and intact — including flanged connections; stacks and ducts are fully insulated. Heating coils may be shipped installed or delivered to job site, pre-assembled on tube supports, as desired.

Shop-assembled or field-erected . . Selas Gradiation heaters will give you extended "on-stream" periods, high conversions and selectivity, Zone Control of heat input, and increased tube life.

May we arrange for a Selas field engineer to discuss your heat processing requirements with you? For this service — without cost or obligation to you — or for a copy of Bulletin "Gradiation Heating for Petroleum and Chemical Processing," write to Mr. M. Kitzen, Selas Corporation of America, 76 Dreshertown Road, Dresher, Pa.

Gradiation is a registered tradename of Selas Corporation of America

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SELAS CORPORATION OF AMERICA
DRESHER · PENNSYLVANIA

HEAT AND FLUID PROCESSING ENGINEERS development · design · construction

For more data on advertised products, use Readers' Service Cards, last page.

HELP WANTED

Process Engineer

BS or MS Chemical Engineer with three to ten years experience in continuous chemical processing involving fluids or solids handling. Preferred type of experience is gathering bench scale data for design of production plant. This opportunity comes about as a result of the continued expansion into new areas.

Send your resume in confidence to:

Technical Employment Manager
Minnesota Mining & Manufacturing Company
900 Bush Avenue
St. Paul 6, Minnesota

REFINERY MAINTENANCE—Two men, one possibly for Maintenance Superintendent, with several years general experience in all phases refinery maintenance: covering, welding, pipe fitting, pump and compressor repairs, instrument, electrical, boiler making, rigging, etc. Mechanical Engineering Degree desirable but not necessary if otherwise qualified. Must be capable of doing work in the crafts themselves, also organizing, training, and supervising our Puerto Rican employees. Salary commensurate with experience and ability. Make application to E. G. Case, Vice-President, Manufacturing, Caribbean Refining Company, Box 2988, San Juan, Puerto Rico.

CHEMICAL ENGINEERS

All Degree Levels Needed Immediately for Process Design and Economic Evaluation

Apply your abilities to the development and design of new process units in the Petroleum Refining, Chemical Processing, Plastics, and all related fields. Two to five years' experience is preferred. Salary commensurate with experience. Location in Bartlesville, Oklahoma, a modern, progressive, southwestern community.

PHILLIPS PETROLEUM COMPANY offers you a challenge and opportunity. Do not delay, write - - -

Personnel Procurement
Research and Development Department
PHILLIPS PETROLEUM COMPANY
Bartlesville, Oklahoma

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NORMAN O. ELDRED
Consulting Chemical Engineer
P. O. Box 3396, Mdse. Mart Postal Sta.
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Complete Petroleum Refinery Design Engineering, Bulk Gasoline and Oil Storage and Terminal Plants, Butane and Propane Storage and Vaporizer Plants Process, Finished Designs, Specifications, Reports, Supervision.

FOR SALE

REFINERY INSPECTION GAUGES
JOHN J. BECKER CO.
BRADFORD, PA.

SITUATIONS WANTED

■ Young graduate engineer—five years refining experience—wants position of opportunity in progressive company, foreign or domestic. Spanish spoken. Write Blind Box 337-R, PETROLEUM REFINER, Houston, Texas.

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Handling costs compel Gulf Publishing Company to make a charge of 25 cents per article for all TEAR SHEETS ordered. Such tear sheets will be sent, when available, if cash (or company requisitions) is sent with the order.

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Address: Reprints, Petroleum Refiner, Box 2608 Houston 1, Texas

Test Yourself

(Answers to Quiz on Page 226)

Case No. 1

Arbitrator John V. McCormick ruled: "The company was faced with a serious problem. Failure to ship the goods would displease the customer and might lead to the loss of the account. In order to solve the problem, employes outside the bargaining unit were put to work. The supervisor, on whom the ultimate responsibility rested, did not follow through by having somebody check the progress of the work from time to time, and he did not learn until very late that the work was not completed. It would seem that the company could have known, by adequate supervision, that the work would not be complete by quitting time. The employes who should have done the work shall be paid the amounts they would have received if they had worked to complete the job."

Case No. 2

Arbitrator Milton H. Schmidt ruled: "The violation of the no-strike pledge cannot be condoned. It warranted the imposition of some penalty or discipline. This the union apparently concedes. I cannot agree with the union claim that refusal of holiday pay to workers who are on a wildcat strike during the holiday week is unjustified because such action is not explicitly spelled out in the holiday-pay article. The withholding of holiday benefits from workers on strike when the holiday occurs is a type of penalty which comes within the definition of discipline. The grievance is denied. Management's action is justified."

Case No. 3

Arbitrator Harry Seligson ruled: "In spite of John Meeker's poor attendance, I am constrained to reverse the company's action in discharging him.

"There was almost a 'mechanical' carrying out of a rule. Absences were recorded. After the company concluded there were enough, a written warning was handed 'mechanically' to Meeker. On other occasions when he was talked to about his attendance he was merely 'told' or 'warned' that he must improve. During this whole period, not once was he called off the floor by his foreman, department head or personnel department for a conference to delve into the causes for his absences. Neither was the cooperation of the union sought, as it had been on other employes.

"If the company insists on asserting its right to manage the working force, it must also assume the responsibility—as part of the management function—to find out the causes behind employe deviations from rules before it imposes punitive discipline. Punitive discipline should not be imposed until a reasonable investigation has been made of the causes, and some attempt made to help him solve the problems that are causing the absences." The penalty was reduced to a disciplinary layoff.

Ranges: 0-20 to 0-200 inches at static pressures to 2000 psi.

new Foxboro Flow Transmitter continues to indicate even without air supply...needs no mercury

Here's a new indicating flow transmitter with safety built right in! Measurement indication is continuous — even if air supply fails.

Moreover, the M/45 Flow Transmitter uses no mercury in its measuring system. Instead, it uses the Foxboro Type 37 diaphragm bellows unit, which responds to differential pressure changes with unmatched sensitivity. And it cannot be damaged by overrange.

Over all accuracy is guaranteed at ±½ of 1%; ambient temperature stability at better than ½ of 1% in 50°F temperature change. Servicing is simple — zero drift virtually non-existent.

The M/45 Transmitter is also available for temperature, pressure, liquid level and dew point.

Ask your Foxboro Field Engineer for complete details, or write for Bulletin 13-30. The M/45's unmatched sensitivity — its low maintenance — make it well worth your consideration. The Foxboro Company, 746 Neponset Ave., Foxboro, Massachusetts.

FOXBORO
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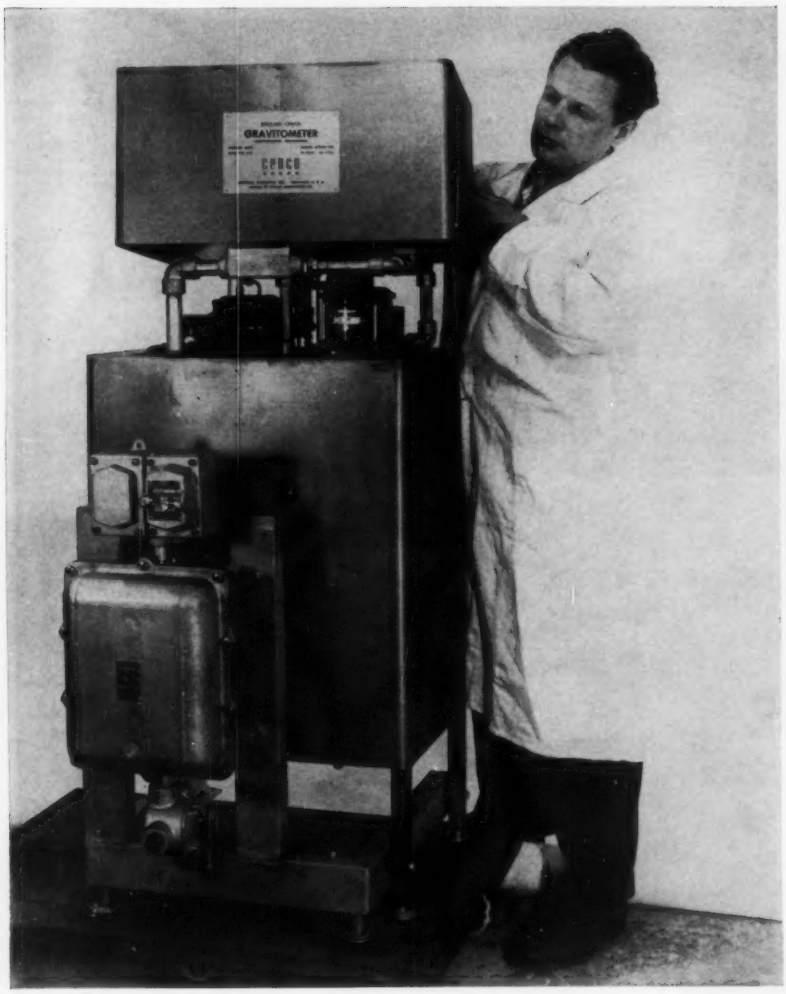
For more data on advertised products, use Readers' Service Cards, last page.

New Equipment & Literature...



Blend Oil, Liquids to Constant Gravity

A new and important instrument recently developed for the petroleum industry by Sinclair Research Laboratories, Inc., is available. Called the Sinclair-Cenco Gravitometer, it can be used to blend crude oil products or a variety of other liquids to a constant outgoing gravity. It is especially designed to direct liquids of differing gravity into specific pipe lines or storage facilities, to continuously measure the gravity of a liquid flowing through a pipe line for the purpose of quality control and to obtain a permanent gravity record. The instrument records the gravity corrected to 60 degrees regardless of the temperature of the flowing liquid.

A small sample of liquid product is continuously taken from a pipe line and pumped into the Gravitometer and through a column of fixed dimensions. As the sample flows through the column it is continuously weighed by means of a differential pressure transducer. The transducer, which is an unbonded strain gage, translates the weight of the sample into an electrical signal. This can be directed to the input of an externally located recorder or to a valve-controlling mechanism, or to both simultaneously.

The Gravitometer has a response time of 30 to 35 seconds and a measuring tolerance of plus or minus 0.1 degree API (plus or minus 0.0008 grams per cubic centimeter) over its wide measuring range. Several measuring ranges are available. Central Scientific Co.

Circle E1 green card, last page

Chromatograph Studies Catalyst Activity

A micro-reactor device, permitting use of the microcatalytic-chromatographic technic with its Model 154D

vapor fractometer, has been developed.

The new device makes it possible to rapidly survey activities of a series of catalysts using a flow-type reactor. Changes in activity of the catalyst, as reflected in composition of the reaction products, can be investigated as a function of time while using only small quantities of reactant. Further, this technique makes possible the study of many other types of reactions.

Operation of the device can be carried out automatically. The substitution of a process-type gas chromatograph for the laboratory version, with suitable valves activated by solenoids and timed by the usual programmer unit, produces an automatic cycling system. This modification presents the possibility of building a "micro-pilot plant." Perkin-Elmer Corp.

Circle E2 green card, last page

Gasoline Additive Ups Spark Plug Life 3½ Times

The introduction of a new preignition control additive for gasoline—"Ethyl" Ignition Control Compound 4, has been

B&W
WELDING
FITTINGS

MADE BY MEN WHO KNOW TUBING

B&W Welding Fittings manufacturing is integrated with the Division's own tube-making and steel-making facilities. Consider the relation between tube-making and the manufacture of welding fittings . . . in addition to knowing welding fittings manufacturing, B&W knows of the making of tubing from which fittings are produced. This knowledge plus integration of facilities permits B&W to provide superior fittings, completely quality-controlled, matched to end-use service. It also means on-time deliveries of fittings made from tubing of the specialized steels because B&W can closely control manufacturing schedules from melt to the shipment of the finished product.

B&W Welding Fittings and Flanges are available through qualified distributors in carbon steel and the B&W CROLOYS in a complete range of types and sizes. Write for B&W Bulletin FB502. The Babcock & Wilcox Company, Tubular Products Division, Welding Fittings Plant, P. O. Box 230, Beaver Falls, Pennsylvania.

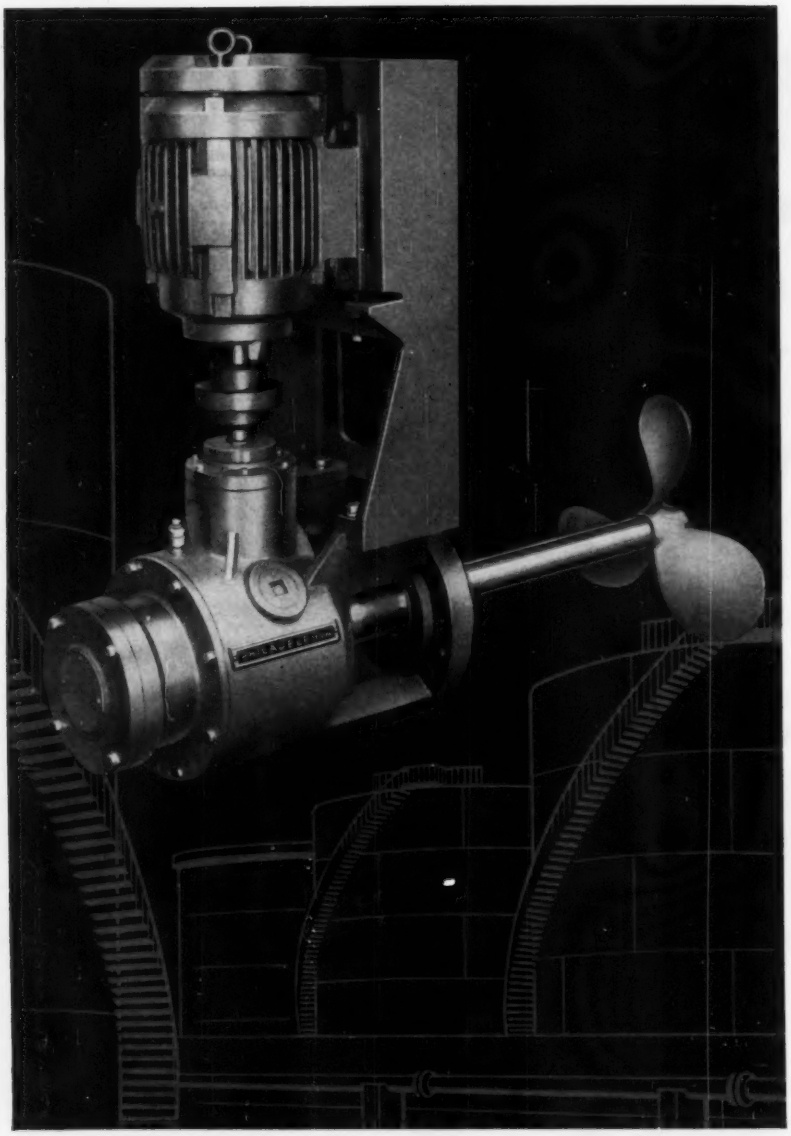
B&W

THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

TA-9079-WF2

Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals

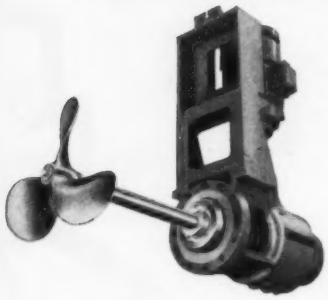


NEW from Philadelphia... SIDE ENTERING MIXERS

And there is plenty that's *new* about them. Shorter, more compact; they minimize the need for mounting braces. Reducer and reducer support stand housing is one piece to provide more rigid support for bearings, shafting and gearing. In short, these new mixers are designed for the job . . . not adapted to it. They overcome all the problems inherent in mixers that are a collection of components designed for other purposes.

And if you are looking for better mixing, these new Philadelphia mixers will deliver it. Large volumetric flow means thorough top-to-bottom turnover, even in the largest tanks. As for cost, Philadelphia side entering mixers cost less than *any mixer* of comparable quality.

NEW
FROM EVERY ANGLE



COMPACT. This is an extremely compact mixer. Weight is centered close to the tank wall. There's less overhang . . . less strain on tank walls and nozzles. Need for bracing at points other than the mounting flange is minimized.

HIGH CAPACITY GEAR REDUCER IN MIXER DRIVE. The capacity of the precision spiral bevel drive, using maximum standard motor sizes, is more than twice AGMA requirements. This means far greater gear life than normally required.

ONE PIECE GEAR REDUCER AND REDUCER SUPPORT STAND HOUSING. Rugged and rigid, it is designed for large, high capacity bearings, and large-diameter shafting. Result: truer running agitator shafting and reduced maintenance.

DEPENDABLE SHUT-OFF ARRANGEMENT. The mechanical seal is a cartridge unit. One man can change it quickly and easily with a full head of liquid in the tank, without moving the mixer in any way.

TRUE RUNNING SHAFTS. Minimum distance from reducer to shaft seal, combined with large diameter shafting, means less run-out at the seal. Mechanical seals last longer. Packed stuffing boxes require far less maintenance.

SIMPLE, FOOLPROOF LUBRICATION. Time-tested oil splash system provides correct lubrication to gears and bearings.

For better mixing, and a better mixer, get all the details. Write for Catalog PSE-60. Sizes: Model 08, 1 to 7.5 HP; Model 11, 10 to 25 HP.

PHILADELPHIA GEAR CORPORATION
King of Prussia, Pennsylvania
(Suburban Philadelphia)

philadelphia mixers

For more data on advertised products, use Readers' Service Cards, last page.

announced.

Known chemically as trimethyl phosphate, the new gasoline additive is said to be highly effective in controlling such automotive combustion problems as spark plug fouling, surface ignition, and rumble.

The new compound provides more phosphorus per pound of compound than any similar preignition control additive, and it is available at a lower cost per pound of phosphorus than any comparable additive.

Extensive tests conducted by Ethyl showed that the use of Ignition Control Compound 4 in gasoline increased spark plug life three to three-and-a-half times, reduced surface ignition by 70 to 80 percent, and greatly reduced the incidence of rumble, which is a form of abnormal combustion similar to knock. Moreover, the tests demonstrated that ICC 4 presents no inductibiilty problems, has a low antiknock destructiveness, and has no effect on the storage stability of leaded gasolines. Further, engine tests showed satisfactory exhaust valve durability, and that the compound has no adverse effect on piston rings or bearings. Ethyl Corp.

Circle E3 green card, last page

Low-Cost Thermometers For Process Equipment

A new line of low-cost, precision thermometers which accurately measure temperatures of hot and cold water lines, heater coils and similar processing and

refining equipment, has just been announced.

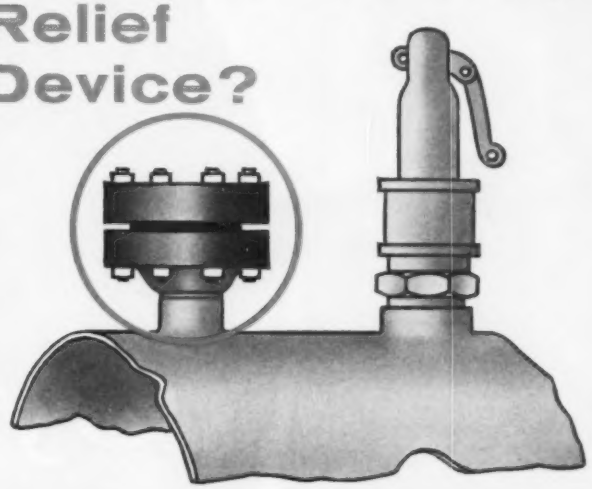
These new economy thermometers are designed for use on refrigeration systems, hot water tanks and generators, oil burner pre-heating coils and other commercial and industrial circulating and storage systems requiring careful temperature maintenance. N.P.T. brass separable sockets (½-inch) are provided for easy installation and unit replacement, and a 2-inch brass extension neck socket is offered for insulated lines. Thermometer cases are available in straight, regular angle, or oblique form. H. O. Trerice Co.

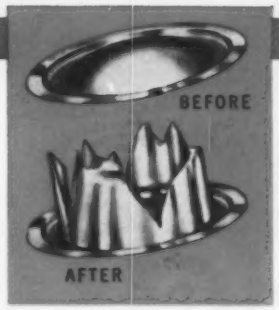
Circle E4 green card, last page

Bulletin On Gas Scrubbers

A new bulletin describes a complete line of ejector-venturi scrubbers, and its venturi throat scrubber, condensing scrubber, cyclonic scrubber, and cyclonic separator. It begins with an introductory discussion of this equipment's use for economical control of fumes, gases, vapor

Why The "Standby" Relief Device?





The BS&B *Safety Head* Takes Over Under Abnormal Conditions

Your relief valve may need a helping hand.
The double protection provided by this relief valve–BS&B Safety Head combination is ideal when—

- **The nature of the pressurized fluid may cause malfunction of relief valve.**
- **Instantaneous over-pressure occurs due to abnormal heat or regulating conditions.**

When pressure-relief requirement is greater than the discharge capacity of the valve, the BS&B Safety Head provides an instantaneous, unrestricted opening.

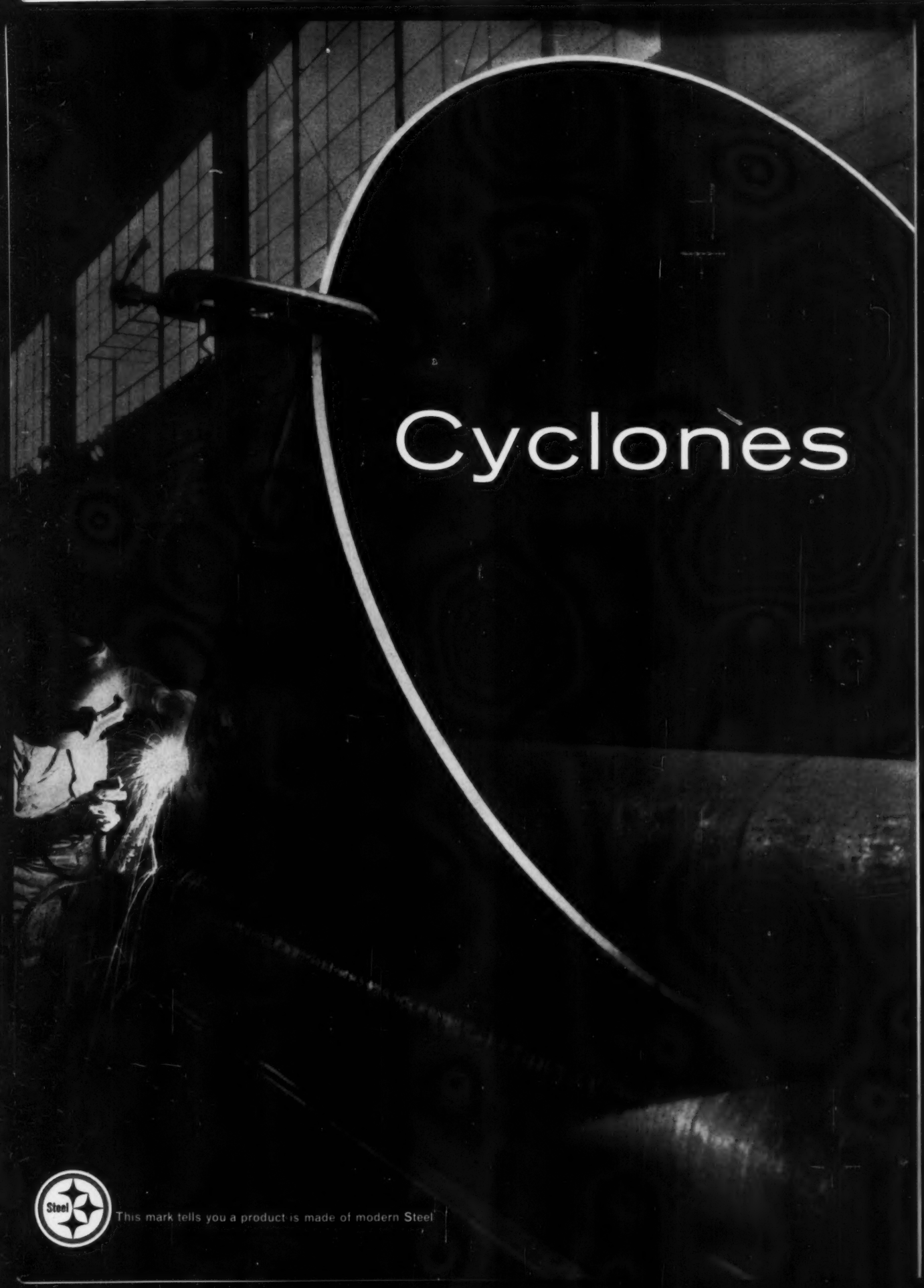
Thousands of pressure systems are now protected with the added security of BS&B Safety Heads.

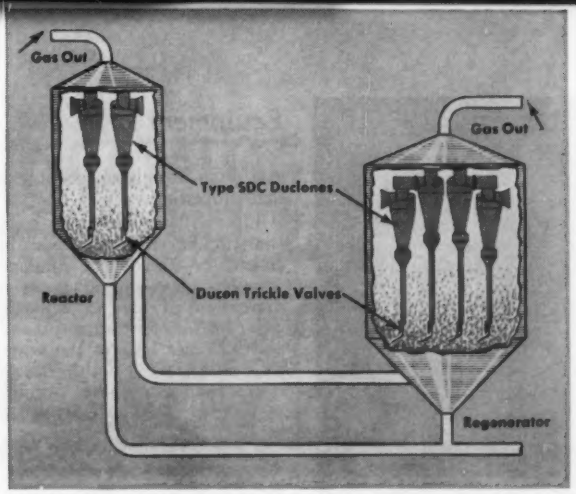
BS&B Engineers will be glad to evaluate your pressure system for application of the correct BS&B Safety Head.

Write, Wire or Phone . . .

BLACK, SIVALLS & BRYSON, INC.
Safety Head Division, Dept. 2-F6
7500 East 12th Street
Kansas City 26, Missouri
Telephone: BEnton 1-7200

For more data on advertised products, use Readers' Service Cards, last page.


Cyclones
Steel
This mark tells you a product is made of modern Steel



General arrangement of Ducon cyclones in the reactor and regenerator of a fluid catalytic cracking unit. Stainless cyclone collectors keep catalyst loss to a minimum. "Duclone" is a registered trademark of the Ducon Co.

start here...

. . . and end up in fluid bed cat crackers where they circulate up to 60 tons of catalyst every minute. At $400 to $500 a ton, lost catalyst can put a lot of red ink into a refinery's operating budget. Breakdowns cost from $20,000 to $50,000 a day. That's why it is so important to design with the right material from the start: USS Stainless Steel.

Stainless Steel cyclones used for catalyst recovery are subjected to extreme heat and erosion. Temperatures in a regenerator unit can go as high as 1400° F. At high temperatures elemental sulfur corrosion would eat out most materials in nothing flat. Not Stainless. And Stainless Steel retains its strength at high temperatures. Stainless cyclones aren't in danger of changing shape which could cause catalyst loss.

Nothing equals Stainless Steel as a solution to the many complex problems in a refinery. It has outstanding corrosion resistance for a wide range of reagents, excellent high temperature strength. Its smooth, dense surface won't harbor contamination, is easy to clean. Above all, USS Stainless Steel promises long life and low maintenance. Order USS Stainless Steel through your USS representative or your local Steel Service Center.

If you are interested in more information about these Stainless Steel cyclones, wire or write U.S. Steel, Room 6104, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS is a registered trademark

Left, welder completes longitudinal seam of one segment of the cyclone at The Ducon Company's Mineola, N.Y. plant. **Below,** stainless steel cone is removed from the forming rolls.

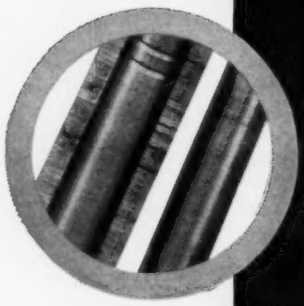
USS

United States Steel Corporation — Pittsburgh
American Steel & Wire — Cleveland
National Tube — Pittsburgh
Columbia-Geneva Steel — San Francisco
Tennessee Coal & Iron — Fairfield, Alabama
United States Steel Supply — Steel Service Centers
United States Steel Export Company

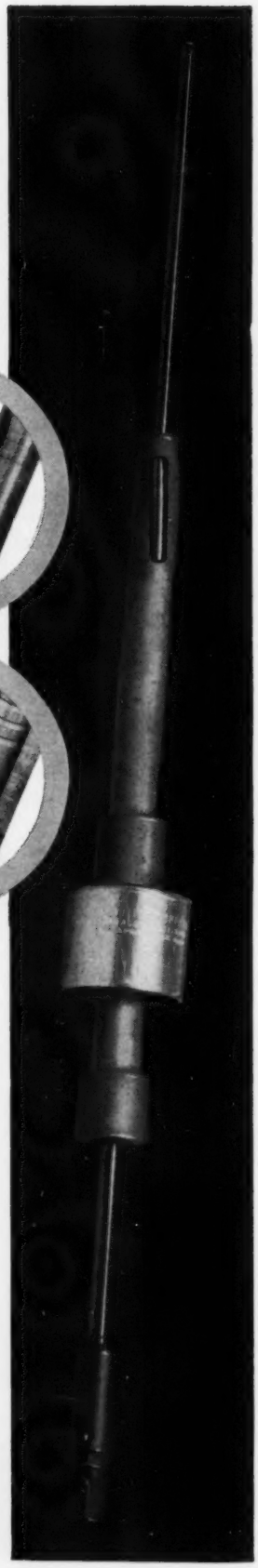
United States Steel

NEW ELLIOTT TUBE EXPANDERS roll tubes into thick sheets in one pass

Use of **NEW** continuous-rolling technique here—shows uniform seal, with all Keys preserved, and no signs of shear



OLD step-rolling method results in non-uniform surface . . . distortion of Keys where rolls have overlapped



Better seal . . . Smoother surface . . . Much Faster operation

This new concept in tube expanders was developed by Elliott to roll the thickest tube sheets. Using a continuous-rolling method, it eliminates many problems common to step-rolling, may be operated protractively or retractively, saves time, assures uniform, smooth surfaces, avoids annular voids or erratic tube inside diameters, provides better seal.

Accessories

Elliott also makes a complete line of retubing accessories, including both electric and air magnetic Tube Rolling Controls, Tube Gages, Tube Plugs, Tube Cutters, etc.—in addition to a complete line of tube expanders. *Ask for Bulletin Y-52.*

ELLIOTT Company
LAGONDA PLANT, SPRINGFIELD, OHIO
Y9-5

Equipment . . .

and dusts in pollution control and chemical processing.

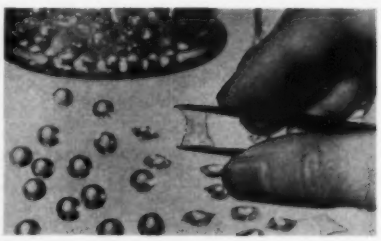
The bulletin then gives application, construction and operation information on each type scrubber manufactured, with complete data on sizes available and dimensions. Tables of gas handling capacities for different water pressures, drafts, and scrubber sizes in the bulletin enable the reader to select the proper type and size scrubber to meet specific operating requirements. Schutte And Koerting Co.

Circle E5 green card, last page

Glass Pillow Fillers For Fractionating Columns

Tiny pillows and balls of glass are being produced as a low-cost material for filler, packing, filtering and tumbling applications.

The pillows include both solid and



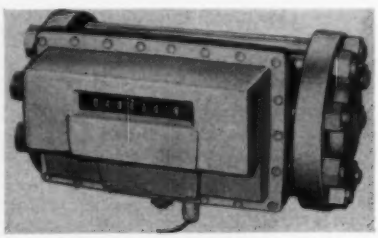
hollow pieces. They are being made in lengths up to one-half inch. The balls can be made to diameters of one-half inch.

The solid pillows are being used in chemical processing as fillers in fractionating columns and in filter beds. Their tumbling action provides the necessary agitation in electroplating operations. Corning Glass Works.

Circle E6 green card, last page

Flowmeter Measures Gas Weight Directly In Pounds

The revolutionary but practical "true mass" flowmeter makes possible the measurement of gas, such as ethylene, directly in pounds, eliminating calculations for



conversion of volume to weight.

Many industries currently use the pound as a fluid measure for figuring costs, regulating, blending, measuring yields and other purposes. Inherent simplicity and the high accuracy—within

NEW CATALOG Describes Latest Developments in Waste and Refuse Storage and Removal

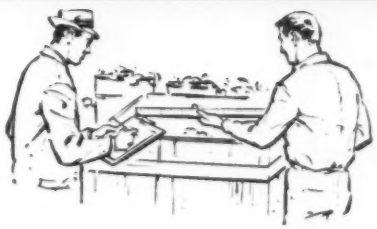
New Techniques Cut Cubic Yard Removal Costs to Record Low

This new 28-page color catalog describes remarkable new developments in waste control and disposal that have, within the last two years, obsoleted many systems now in use. Cubic yard handling costs have been reduced to a point where many firms and municipalities are saving thousands of dollars annually that they were previously spending to operate old-style equipment.

Materials handling and waste disposal are two of the few areas of large potential cost reduction remaining in manufacturing and municipal administration. This new catalog has a bearing on both of these areas of operation.

To get your copy of this new fact-filled catalog, write today.

DEMPSTER BROTHERS
Inc.
DEPT. PR-6 KNOXVILLE 17, TENN.



FREE SURVEY WITHOUT OBLIGATION
Dempster Field Engineers, located in all sections of the country, make thousands of cost-finding refuse storage and collection surveys every year, without cost or obligation. If you would like to know your disposal costs, and what—if any—avenues of improvement exist, write today on your letterhead.

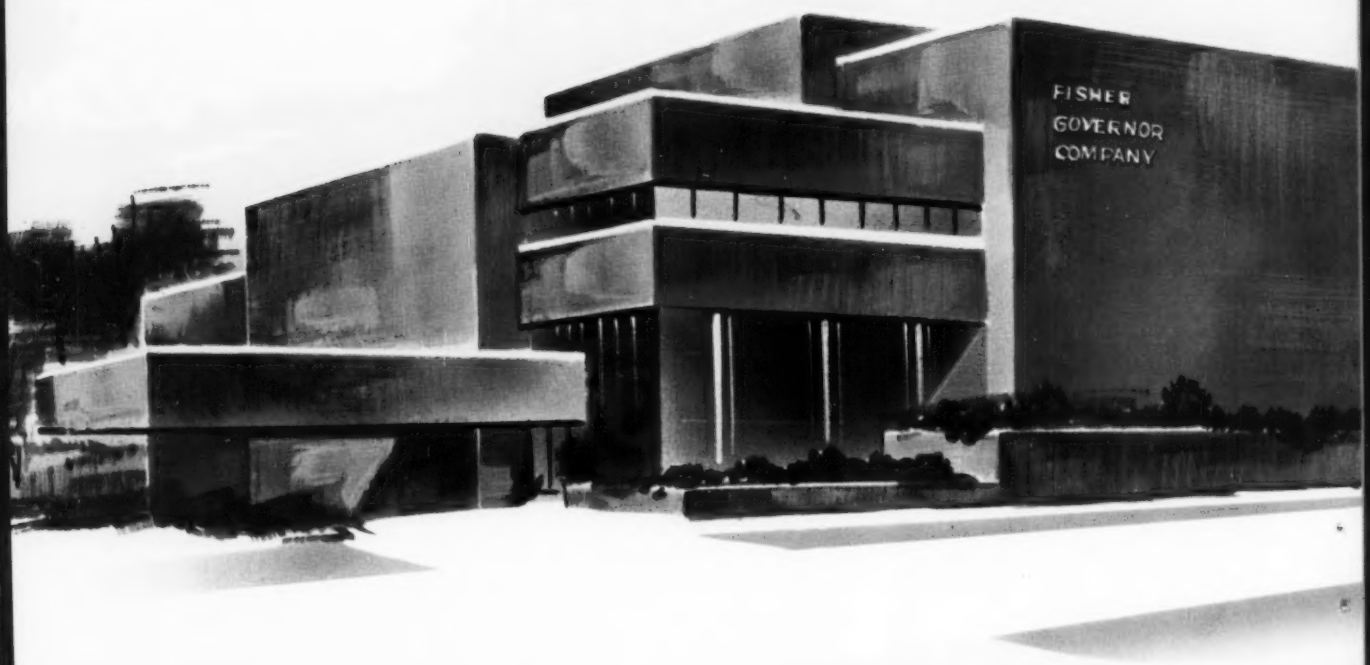
28 Page Catalog FREE

Dempster Brothers, Dept. PR-6
Knoxville 17, Tennessee
Please Send New Catalog Brief 160

Name _____
Title _____
Firm _____
Address _____
City _____ State _____

For more data on advertised products, use Readers' Service Cards, last page.

FISHER . . . . *an unparalleled*



Standing firmly behind every Fisher product is the "know-how" and motivating spirit that has guided the Fisher organization since 1880. These, combined with the remarkable engineering and manufacturing facilities illustrated and described here, have made possible the slogan: "If it flows through pipe anywhere in the world . . . chances are it's controlled by FISHER."

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / Rochester, England

BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT COMPANY, CORAOPOLIS, PA.

CONTINUOUS ADVANCED RESEARCH

Increasingly severe service conditions are encountered daily in the fields of nuclear power and cryogenics. To meet these conditions, Fisher research maintains a continuous program for development and use of new metals and materials.

PRACTICAL DESIGN ENGINEERING

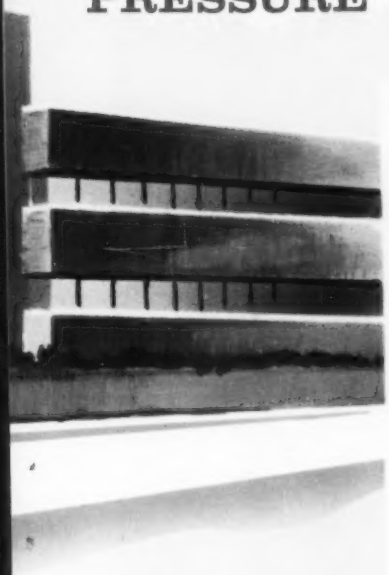
Design engineering at Fisher is always aimed at solving industry's flow control problems, practically and efficiently. Over 80 years of development and improvement has resulted in a full line of controls of proven durability and performance.

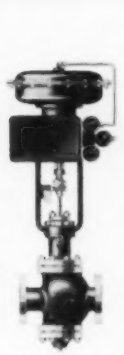
TESTING AND DEVELOPMENT

Representative of the very latest and finest in equipment, that aids Fisher engineers in the development of new and improved products, is the recent addition of a test line that is capable of handling pressures up to 2500 psi, air or water.

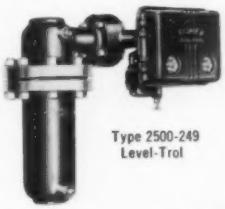
engineering and manufacturing facility

....to build better
PRESSURE AND LIQUID LEVEL CONTROLLERS



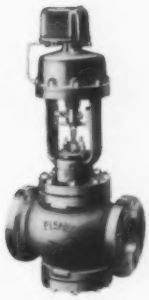


Type 657-A
Diaphragm
Control Valve

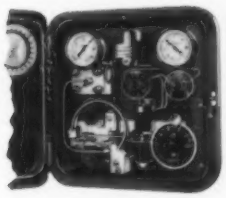


Type 2500-249
Level-Trol

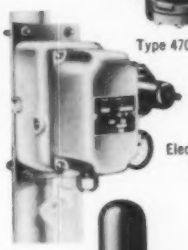
Series S100
Gas Service
Regulator



Type 470 P.O.P.

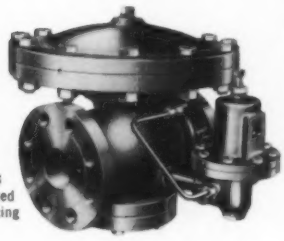


Wizard II
Pressure Controller

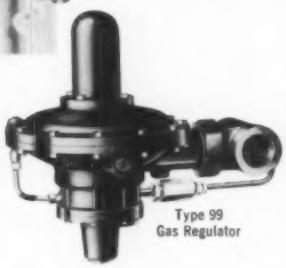


Type 543
Electro-Pneumatic
Transducer

Type 350
Electro-Hydraulic
Control Valve



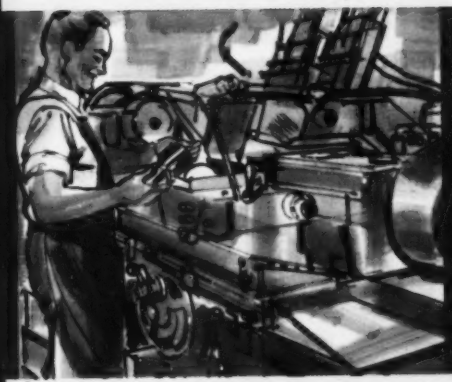
Type 92-B
Pilot-Operated
Steam Reducing
Valve

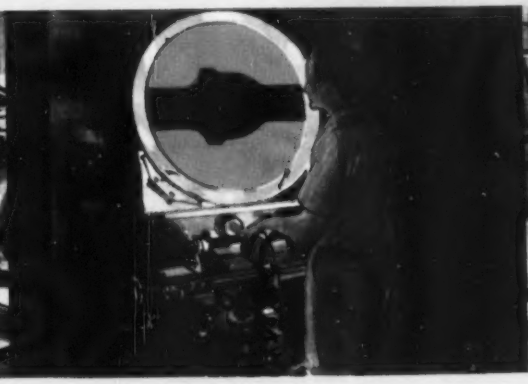


Type 99
Gas Regulator

FISHER® Controls

SINCE 1880

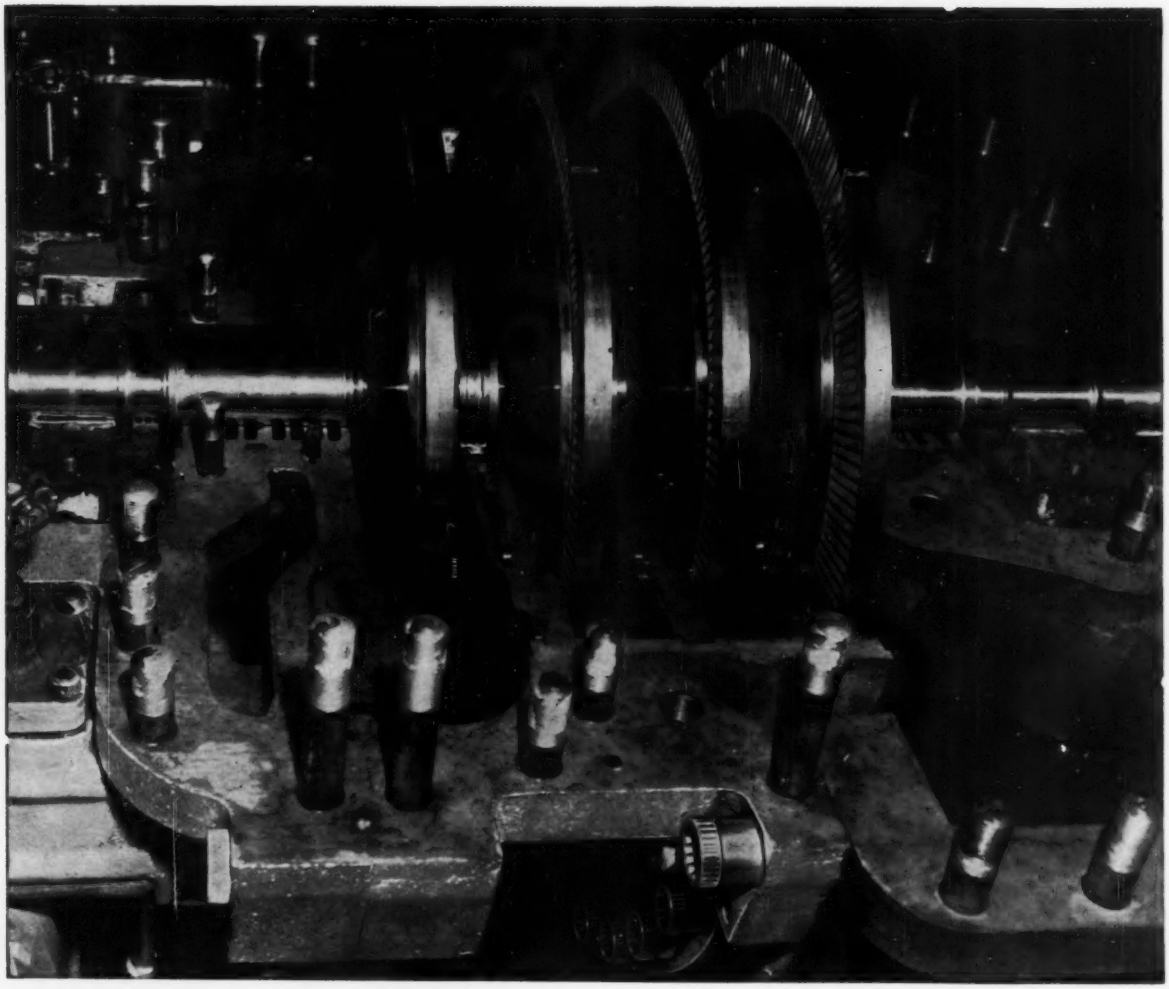




LATEST PRODUCTION METHODS
Various new style grinders produce a super-finish on Fisher valve guides and bushings, second to none in the industry. It is typical of precision manufacturing methods that assure long, trouble-free operation of Fisher controls in the field.

RIGID INSPECTION PROCEDURES
The highest ratio of inspection personnel to production personnel, in the control valve industry, is maintained at Fisher. As a typical example, there are no less than 704 inspection operations performed on a 4" Type 657-A diaphragm motor valve.

EFFICIENT FIELD SERVICE
"Supermarket" 36-hour delivery, from the factory, on popular sizes and types of controls is only one of many services available to Fisher customers. 17 sales offices throughout the country maintain field stocks for immediate delivery.



THE INSIDE STORY OF A MURRAY HIGH SPEED COMPRESSOR

DRIVE TURBINE REVEALS THE REASONS FOR MURRAY'S UNIVERSAL ACCEPTANCE

A look at MURRAY'S rugged construction from the inside shows the husky shaft and heavy accurately formed discs with generous sized hubs designed to withstand the axial and radial stresses imposed by this type of service.

Large-dimension disc rims receive the specially contoured stainless steel blades with the Murray integral shroud. This insures smooth steam passages with maximum strength.

Short bearing spans insure smooth operation and eliminate the hazard of operating in critical speeds.

A look at the heavy flanges and husky bolting in the actual unretouched shop photo shown above bears out the extreme ruggedness that typifies every feature of Murray construction.

Our nearest representative will gladly help you solve your high speed compressor drive turbine requirements. Just write to Murray Iron Works Company, Burlington, Iowa, for his name.

Murray
TURBINES

MURRAY IRON WORKS COMPANY • BURLINGTON, IOWA
Builders of Steam Power Equipment for Nearly a Century

Equipment . . .

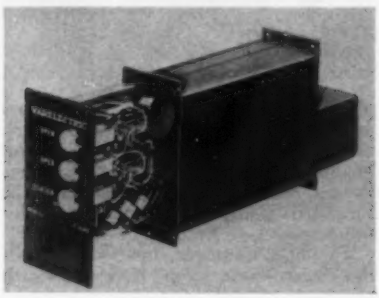
one percent of reading—under changing conditions, makes the mass flowmeter well suited for these operations. Before development of the mass flowmeter, volume of the fluid flow was measured and converted to mass by time-consuming computations that left wide margins for error, or by complex automatic correction systems that added to maintenance burdens.

The new mass flowmeter utilizes a sensing device that consists of a constant speed impeller and a stationary turbine arranged for axial flow. The impeller gives a twist to the fluid stream and the fixed turbine straightens the stream. The torque exerted on the turbine is proportional to the mass rate of flow. A small gyroscope automatically totalizes the flow by integrating the torque with respect to time, permitting the output to be continuously summed up on a dial reading in pounds. Black, Sivalls & Bryson, Inc.

Circle E7 green card, last page

Two-Wire Control System Cuts Field Wiring Costs

Varelectric, a newly-developed *two-wire* supervisory control system that provides direct, instantaneous control of pump motors, valve operators, and similar equipment, is available. It continually supervises and indicates the status of the controlled device and uses only one wire between each control and field unit, plus one conductor common to many units.



Since Varelectric only needs two wires, it offers new economy in process industry applications. The system may cut field wiring costs to as little as 25 to 15 percent of that of conventional systems, which often require from seven to nine wires between individual units. The basic principle of operation involves the inherent polarization characteristics of a direct current power source for remote control and the special ability of a Wheatstone bridge circuit to recognize conditions and direction of unbalance. The wiring is not critical and the signal is a direct, continuous current. No power is required at the field end.

Designed for new installations or additions and supplements to existing installations, this new two-wire system is said

No one coating is ideal for all applications. A coating which gives outstanding protection against chemical fumes in a refinery may fail completely when exposed to salt water splash, high humidity or hot sun on an offshore rig in the Gulf area.

In order to provide complete corrosion protection, the Amercoat Corporation manufactures more than 40 completely different products, each formulated to give maximum corrosion protection for specific applications. As new processes and techniques alter exposures and requirements, Amercoat's continuing research develops new products to meet those requirements. Also, advanced research and testing upgrades and improves existing products to maintain maximum protection and enduring, maintenance-free life. Amercoat protective coatings, ranging from vinyls to epoxies to phenolics, are tailor-made for long-range protection and economy in tough applications.

DIMETCOTE—a 100% inorganic, zinc silicate coating for severe weather exposure, salt water spray, fresh water, etc.
Typical applications: Offshore rigs, floating roof tanks, steel structures, pipelines, cooling tower piping, etc., and as a permanent primer.

AMERCOAT No. 33—A vinyl maintenance coating unexcelled for water immersion, chemical spillage or corrosive fumes.
Typical applications: Tank exteriors, pipelines, etc.

AMERCOAT No. 78—A catalyzed coal tar epoxy for exceptional resistance to severe chemical exposures.
Typical applications: Sour crude storage tanks, pipelines

BONDSTRAND—A corrosion resistant, high strength glass reinforced epoxy pipe.
Typical applications: Gathering lines, cooling lines, tanker loading lines, oil and gas lines.

Technical data available on request. Write to:

Amercoat® CORPORATION

Dept. VF
4809 Firestone Blvd.
South Gate, California

124

921 Pitner Ave.
Evanston, Ill.

360 Carnegie Ave.
Kenilworth, N.J.

2404 Dennis St.
Jacksonville, Fla.

6530 Supply Row
Houston, Tex.

For more data on advertised products, use Readers' Service Cards, last page.

Equipment . . .

to offer the petroleum, chemical and other process industries the most reliable and economical control of their electrically operated equipment. The Vapor Recovery Systems Co.

Circle E8 green card, last page

Wedge Disc Gate Valves Will Not Stick Closed

A new line of 150 and 300-pound steel flexible-wedge disc gate valves with a new flexible-wedge disc has been introduced.

The working pressure of the 150-pound valve ranges from 40 psi at 1,000° F to 275 psi at 100° F. The 300-pound valve has a range from 85 to 720 psi at a similar temperature range.

Flex Gates operate easily, even if closed while hot and then permitted to cool. As the body seats pinch the disc, it flexes slightly to conform to the new seating position. The valves do not stick closed; they seat and unseat with minimum torque. No sticking means minimum scrape and wear of the disc and the seats. Crane Co.

Circle E9 green card, last page

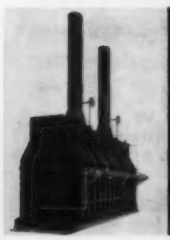
EVEN AMONG SPECIALISTS, SOME STAND OUT!

Only welders coded for work with fired pressure components are entrusted with the precise welding jobs necessary in the fabrication of UNI-RAD Heaters. From the drawing board to shipping and servicing, UNI-RAD Heaters are under the constant supervision of specialists.

UNI-RAD Heaters give more heating power at less cost by providing optimum heat recirculation. Available in either horizontal or vertical models, the units can be engineered to deliver from one-half million B.T.U.'s to unlimited capacity.

Maintenance presents no problem as all standard parts are easily replaced. A full-time staff of Anderson service engineers is ready to assist you anywhere at any time.

For quality heating equipment, you can rely on UNI-RAD!

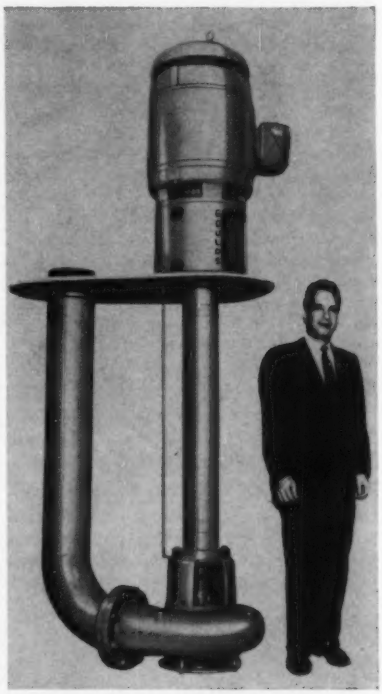


THE K.W.ANDERSON CO.

PO BOX 660, TULSA, OKLAHOMA

Vertical Centrifugal Pump Has 3,000 gpm Capacity

The addition of two new sizes to a line of heavy duty vertical centrifugal sump and process pumps increases the capacity range from approximately 1,000 gallons



per minute to over 3,000 gallons per minute. The new sizes—6- and 8-inch discharge units—are available for pit depths of from 3 to 20 feet for either dry-pit or wet-pit service, and can be furnished in all iron, bronze-fitted or stainless-steel construction.

The open impeller used on all units has ejector vanes on the back side which effectively prevent entrance and jamming of solid materials between the back of the impeller and the stationary side plate.

For vapor proof handling of toxic or hazardous liquids all possible points of leakage of vapor or fumes are sealed and an upper stuffing box is supplied which also has a water jacket for cooling. Maximum temperature of liquids handled in standard construction is 200° F. Wtih stuffing box and quench gland cooling, liquids with temperatures up to 350° F can be handled. Goulds Pumps, Inc.

Circle E10 green card, last page

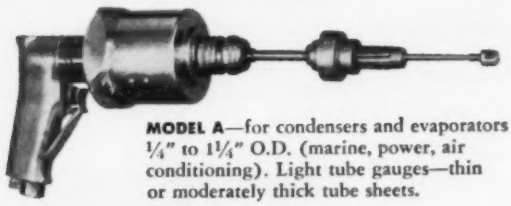
Multi-Component Blending System Covered In Bulletin

A technical bulletin entitled, "Electronic Autoblender" has just been released. The bulletin gives detailed technical information, illustrations, layout flow charts and operational information on a new electronically controlled, multi-component blending system recently introduced. The system is fully automatic and the manufacturers claim an exceptionally high degree of accuracy on a continuous

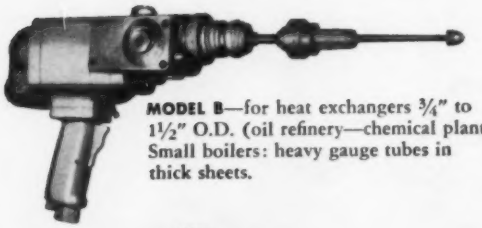
Now for every tube . . . every size . . . every type of job

WILSON
TORQ-AIR-MATIC
AUTOMATIC EXPANDER DRIVES AND ACCESSORIES

WILSON offers a complete line of Torq-Air-Matic automatic tube expander drives and torque controls. Wilson was the first to successfully develop an air driven tube expander drive that accurately controls tube expansion, by directly measuring torque output at the mandrel, without depending on frictional, ratcheting, magnetic, hydraulic or electrical devices. Hundreds are in successful use by many manufacturers and repair men the world over.



MODEL A—for condensers and evaporators ¼" to 1¼" O.D. (marine, power, air conditioning). Light tube gauges—thin or moderately thick tube sheets.



MODEL B—for heat exchangers ¾" to 1½" O.D. (oil refinery—chemical plants). Small boilers: heavy gauge tubes in thick sheets.

TUBE EXPANDERS—Wilson Models 41 and 44 Self-Feeding Tube Expanders are modern tube expanders for the *precision rolling* of condenser and heat exchanger tubes into the heavy tube sheets used in current practice.

TUBE CUTTER—Rugged and economical for use with a portable drill, for cutting off tube beyond the tube sheet.

TUBE PILOT—New Guide-Rite plastic guide inserted into tube end for easing tubes through sheet and support plates.

TUBE KNOCKOUT TOOLS—For hand or mechanical use.

Write for comprehensive Catalog 77-88.

Representatives in principal cities

THOMAS C. WILSON, INC.

21-11 44th Ave., Long Island City 1, N. Y.

Cable Address: "Tubeclean," New York

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BETTER TOOLS FOR BETTER WORK

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with UROX® Weed Killer

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Longer lasting! Economical! One application gives you 8 to 18 months control. And effects are cumulative. Light "booster" doses extend control from year to year.

Available in 2 easy-to-use forms! *Liquid* UROX Weed Killer is ideal for spraying large overgrown areas. Won't clog spray nozzles or strainers. Does not precipitate out in the tank. Stays in solution perfectly. *Granular* UROX is the convenient, inexpensive way to treat small weed-infested areas. Can be applied quickly and easily with any mechanical or hand-operated spreader.

Send coupon today for free folder on the use of nonflammable UROX to prevent brush and weed fires!

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For more data on advertised products, use Readers' Service Cards, last page.

Type 800

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Uniflow

BAR STOCK AIR OPERATED CONTROL VALVES

In sizes ¼" to 1" with body ratings to 15,000 psi in steel, 15,000 psi in stainless and 800 psi in brass. Straight-through or Angle Type valve bodies, 3-15 psi, Air to open—Air to close.

- Flow Co-efficient: Cv. .00001 to Cv. 3.0 with Linear Plug and removable seat are standard construction.
- Parabolic & equal % plugs Cv 0.55 to Cv 6.0
- Complete design features to meet your specifications.
- For special applications—body and trim material can be furnished in Monel, Aluminum, and Hastelloy "C"
- Optional features available: Bellows Seal, Cooling Fins, Top Mounted Moore Valve Positioners, Weld end Bodies and Side Mounted Foxboro Positioners.

Write for Bulletin No. 116.

Uniflow Valve Corporation

30 QUINE ST., CRANFORD, NEW JERSEY • BRidge 6-8300

you don't have to increase pump speed

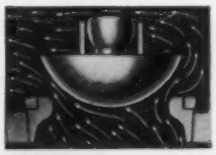
...to get GREATER PUMP VOLUME

in fact ... the revolutionary Royal Crown Pump Valve increases pump volume with less pump speed! Here's how it operates: Valve is guided by a frictionless ball stem (not a rigid guide) which allows it to oscillate and turn freely with the fluid stream with a minimum of resistance. The result: greater pump volume at a slower pump speed for maximum pump efficiency and economy. Royal Crown Valves have only three separate parts which assures long, trouble-free service. Adaptable to all reciprocating pumps and all liquids.

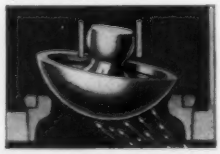
Royal Crown PUMP VALVES

WRITE FOR FREE LITERATURE TODAY

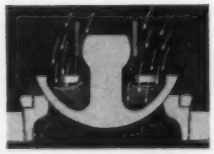
Round valve surface is streamlined. No crossbars or obstructions in seat to restrict the flow of liquid.



Ball-guided valve rotates and swings with each stroke of the pump. Each turn, each swing a lapping action – a perfect seat.



Free vertical action assures instant opening and closing. Ball stem is a frictionless guide.



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BALDWIN-LIMA-HAMILTON CORPORATION, LIMA, OHIO

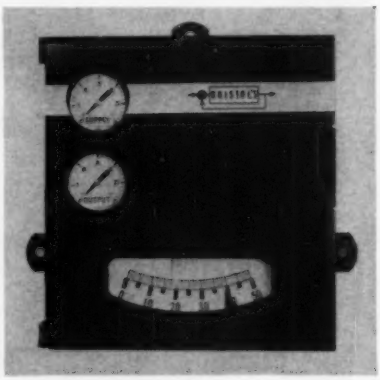
Equipment . . .

and variable blending operation. Either electric or pneumatic controls are employed with all manifold components, such as piping, pumps, meters, valves, mixers and dehydrators being controlled from one master controlled unit. The electronic circuit is fully transistorized with printed circuit plug-in cards and built-in checking facilities. The master control unit or panel may be located anywhere within a half mile of the blender components. Automatic Control Div., Constructors John Brown Ltd.

Circle E11 green card, last page

Pneumatic Controller Gives Closer Process Control

A new line of position-balance indicating controllers, known as A/D (advance design) Model 624 Pneumatic Controllers, has been announced. These



instruments, currently in production, feature simple modular design for ease of servicing, and high control stability for closer process control.

The new controllers are available in models for proportional control with 1 to 400 percent proportional band, and reset control with 0.1 to 50 repeats per minute reset rate. They are offered for control of pressure (full vacuum to 10,000 psi), temperature (minus 100°F to 1,000°F), flow and differential pressure (both mercury and dry-type meter bodies), humidity (0 to 100 percent RH), and differential liquid level. They are equipped with standard precision measuring elements. The Bristol Co.

Circle E12 green card, last page

Bulletin Has Performance Data On Chromatographs

Industrial gas chromatographs, widely used for stream analysis in chemical plants, refineries, and numerous other process industries, are fully described in a new 12-page bulletin.

The brochure provides complete details and specifications on the construction, performance, operating features, and

KOCH FLEXITRAYS

HELP DX SUNRAY TRIPLE HIGH-OCTANE OUTPUT

Installed to carry out DX Sunray's objective of marketing high-quality products, the new UOP* processes placed on stream at their West Tulsa refinery are the most modern available . . . and includes one of the tallest towers in Oklahoma.

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Flexitrays often save refineries and chemical plants as much as 40% in total cost of completed tower installations. Flexitray's spectacular success has resulted in the use of this low-cost tray in more than 1400 installations. In planning YOUR next tower, be sure to investigate Koch Flexitray . . . for wide flexibility, higher capacities **and** higher efficiencies!

* UNIVERSAL OIL PRODUCTS CO

See our catalog in "Refining Catalog," or contact your nearest Koch Representative

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Kansas City 13, Missouri, Sample Brothers, P. O. Box 7061
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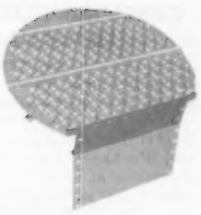

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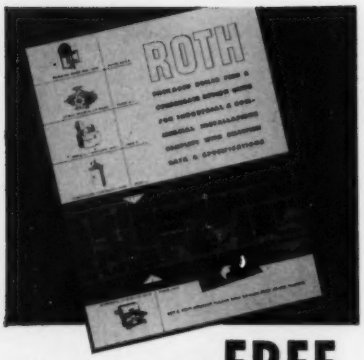

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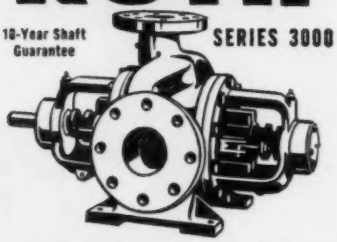
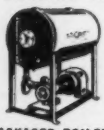
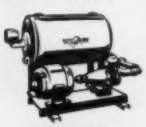


TURBINE POWER PLANT PUMP



PACKAGED BOILER FEED UNITS



HORIZONTAL CONDENSATE UNITS

VERTICAL CONDENSATE UNITS

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CERTIFIED HOT WATER PERFORMANCE

Long, efficient, trouble-free operation under the most adverse conditions of usage, plus a wide range of stock models and capacities, have made ROTH Turbine Power Plant Pumps and Packaged Units the choice of thousands of heating engineers. The pumps are recognized for their superior hot water performance, (capacities and pressure *certified* upon request). Shafts are guaranteed for ten years against breakage. Cast iron or copper-bearing steel available on all vertical and underground units. Motors and controls of nationally accepted makes.

ROY E. ROTH COMPANY
TURBINE PUMP DIVISION
2444 Fourth Avenue • Rock Island, Illinois

Equipment . . .

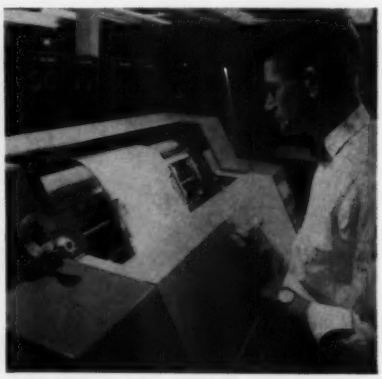
applications of the publisher's instruments. Also included are installation and product photographs, flow diagrams, chromatograms, and dimensional drawings.

The two instruments (120A and 220A) offer accurate resolution, easily adjusted programming, drawer-type module construction in the control unit, and flexibility for multiple-stream and multiple-component analysis. A wide choice of accessories and complete application engineering are available with both gas chromatographs. Beckman Scientific and Process Instruments Division.

Circle E13 green card, last page

More Data Processing Per Dollar Using New Computer

A "new-generation" computer, the most powerful available in the moderate-price field, will make high-speed electronic data processing economical for



thousands of additional companies because it provides more data processing per dollar spent than any previous equipment of similar size.

The basic Honeywell 400 model—with a powerful central processor, four high-speed magnetic tape units, a high-speed printer and a card reader—will rent for $8,660 a month. It will be available in summer 1961.

The central processor of the Honeywell 400 will function at an internal speed of up to 6,000 operations, such as additions or subtractions, per second. The core memory capacity will be 1,024 words of 48 bits each. All information passing through the central processor will be checked internally as it is read from or written on the magnetic tape. The system will be capable of performing both reading and writing operations simultaneously. High-speed printing can be performed simultaneously with any other operation.

The transfer rate of information to or from the high-speed magnetic tapes will be 64,000 characters or 96,000 decimal digits per second. Orthotronic Control, a unique feature on Honeywell data processing systems, will automatically detect and correct any errors in or damage to information recorded on the magnetic tapes.

The high-speed printer will operate at 900 lines per minute, while the card reader will handle 650 cards per minute. Minneapolis-Honeywell Regulator Co.

Circle E14 green card, last page

Monitor Nameplate Has Larger Engraving Area

A new nameplate, called the Magna-Plac, which permits 70 percent more engraving area is optionally available at no extra charge on De-Line annunciators.

The increased area in the nameplate

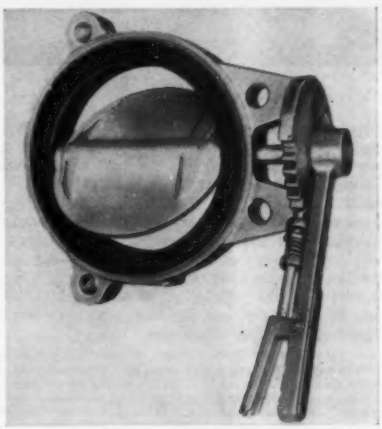
will give engineers an opportunity to more fully describe condition variations monitored by the system, or to employ larger characters which will be more easily readable at greater distances.

The elimination of a metal frame around the white translucent acrylic cover provides the added area. The permanently hinged, heavily molded one-piece plastic cover, which will not chip or discolor, is locked with a captive thumb screw. Scam Instrument Corp.

Circle E15 green card, last page

Butterfly Valve Costs Less Than Gate Valve

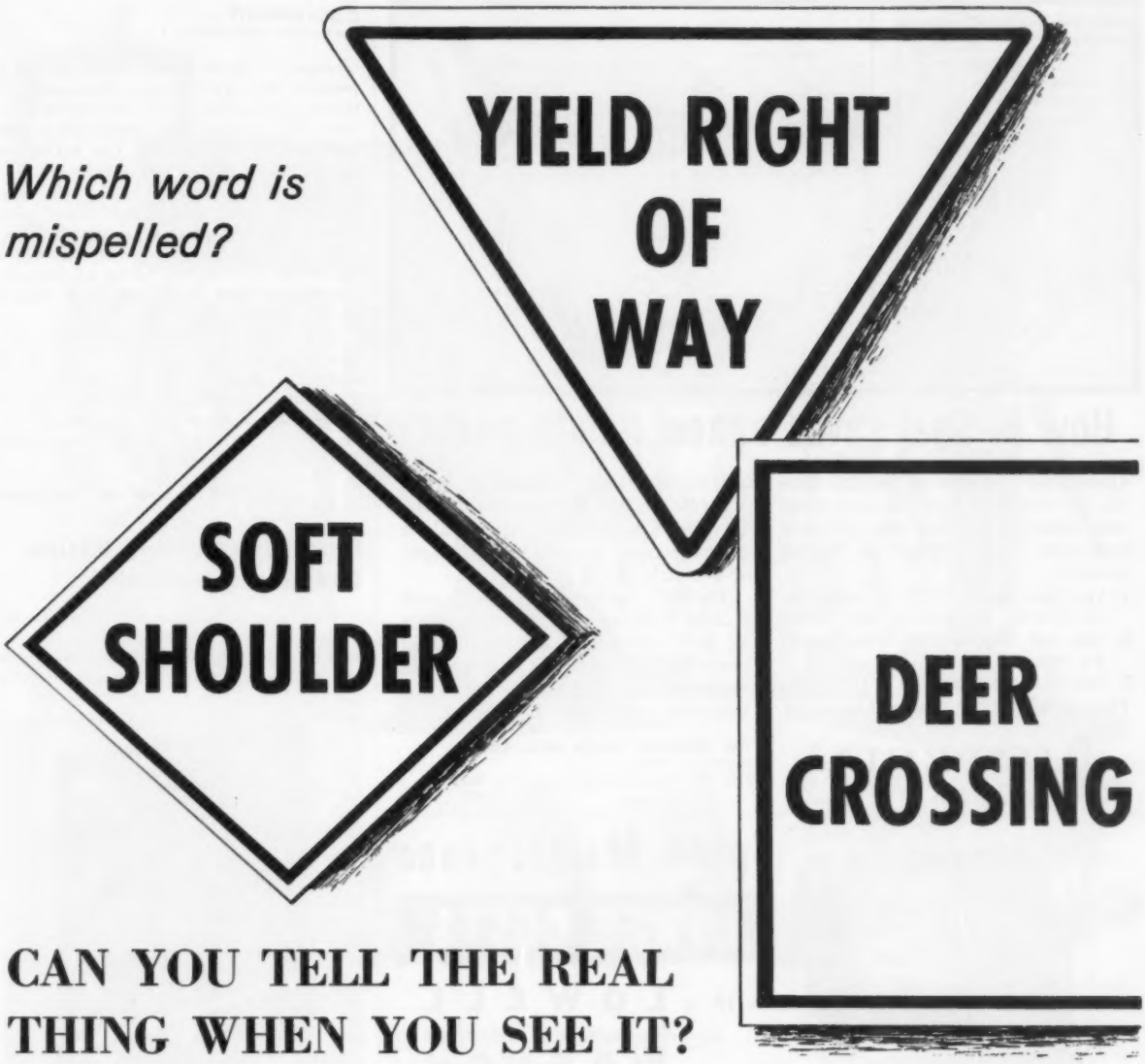
For flow applications where positive, drop-tight shut off and/or resistance to corrosion are important requisites, the



new Resilient Seated Butterfly Valve offers many advantages.

This valve is much smaller in overall dimensions and weighs but a small fraction of that of a gate valve. For example, an 8-inch butterfly valve is 2½ inches face-to-face, 8⅜ inches from center line

Which word is mispelled?



CAN YOU TELL THE REAL THING WHEN YOU SEE IT?

In spelling, or shipping . . . it's all too easy to miss out on important details.

Take liquid caustic . . . and the economic advantages of barge shipment. Our studies reveal that a great many caustic users who could profitably receive shipment by barge are not doing so. If you are situated near a navigable waterway, you may be one of them . . . and we may be able to help you find out. Call on us. We can ship caustic to you by barge or ocean tanker, truck or tank car . . . from Geismar, Louisiana, or from Wyandotte, Michigan. You write the ticket. We'd like to help you write it correctly.

Wyandotte offers a number of chemicals for the petroleum industry, including materials for drilling muds, gas dehumidification, demulsifying, emulsifying, secondary recovery, water treatment, cementing, sweetening and many other petroleum, refinery, and petrochemical applications. Get full details from your distributor, or write: *Wyandotte Chemicals Corporation, Wyandotte, Michigan. Also Baton Rouge, Louisiana. Offices in principal cities.*

ANSWER: The word misspelled is "mispelled." Did you miss that missing S?

WYANDOTTE CHEMICALS
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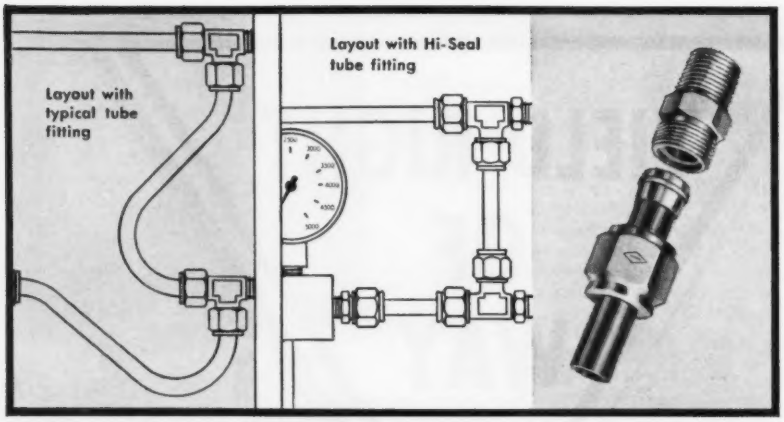
Pacing progress with creative chemistry®

For more data on advertised products, use Readers' Service Cards, last page.



How Hi-Seal saves space...cuts costs

These two sections of typical tubing layouts show how you save time and money using Imperial Hi-Seal butt-joint tube fittings in tubing circuits:

1. You save up to 50% on space requirements by making butt joints.
2. You use less tubing. Fewer bends are required.
3. You cut man-hours in installation.

There's no danger of over-torqueing a Hi-Seal fitting. You can *see* when a Hi-Seal joint is tight. When the threads are covered, the seal is pressure-tight *beyond the strength of the tube itself.*

Hi-Seal conforms to J.I.C. and A.S.M.E. standards . . . is available in steel, stainless, aluminum and brass for ⅛" to 1½" O.D. tubing. Write for Catalog 3108 or call your Imperial industrial distributor.

IMPERIAL

THE IMPERIAL BRASS MFG. CO.
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6300 West Howard Street, Chicago 48, Illinois

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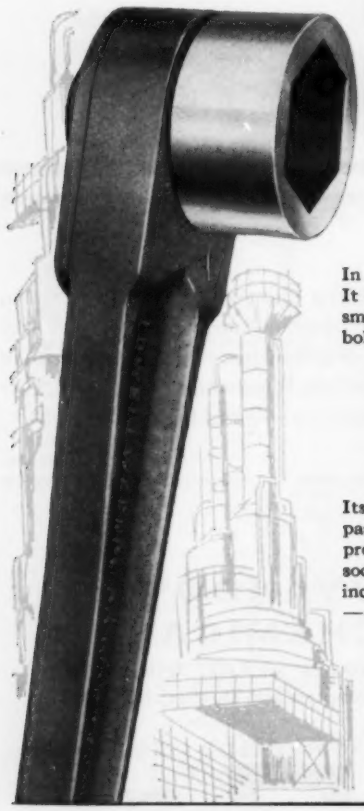


Speed Maintenance
LOWER COSTS
with a LOWELL Reversible Ratchet WRENCH

In any refinery, this wrench is a sure time saver. It works fast. That's the real advantage of its smooth operating ratchet . . . a man can do any bolting job just as fast as he can turn the handle:

making pipe connections, opening and closing valves, overhauling pumps, compressors and heat exchangers, general maintenance and repair—these are all important refinery jobs that can be done quicker with this sturdy Lowell wrench.

Its exclusive hole-thru feature allows the bolt to pass through the head—so bolt length is no problem. And each handle takes a variety of socket sizes. *Standard sizes: Handles*—8 inches to 6 feet long; *Square or Hex Sockets*—up to 9⅛ inches.

Call your local distributor first for Lowell Wrenches or write for catalog information to

LOWELL WRENCH CO.
115 Temple St., Worcester, Massachusetts

Equipment . . .

of pipe to top of valve and weighs 37.5 pounds. An equivalent 150-pound designed gate valve is 11½ inches face-to-face, 29½ inches from center line to top and weighs 320 pounds. The saving in space, weight and cost is obvious.

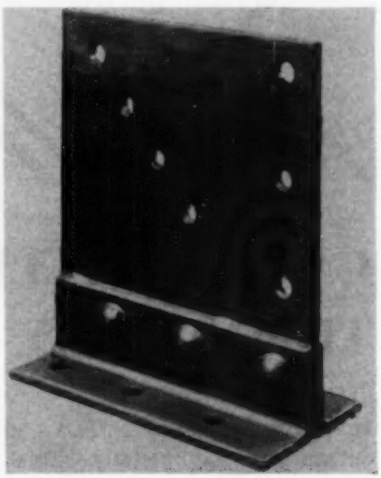
In the new butterfly valve, the disc travels from full open to full closed position in only a quarter of a revolution, with equalized pressure on the disc. There are not mating metal surfaces to corrode or bind, so operation is always simple, positive, and fast.

The streamlined shape of the disc enhances straight-through flow of the fluid without changes in direction. There are no voids or cavities in the valve body to cause eddy currents or fouling with foreign matter. Pressure drop is extremely low. W. S. Rockwell Co.

Circle E16 green card, last page

Protective Coating Resists Chemical Permeation

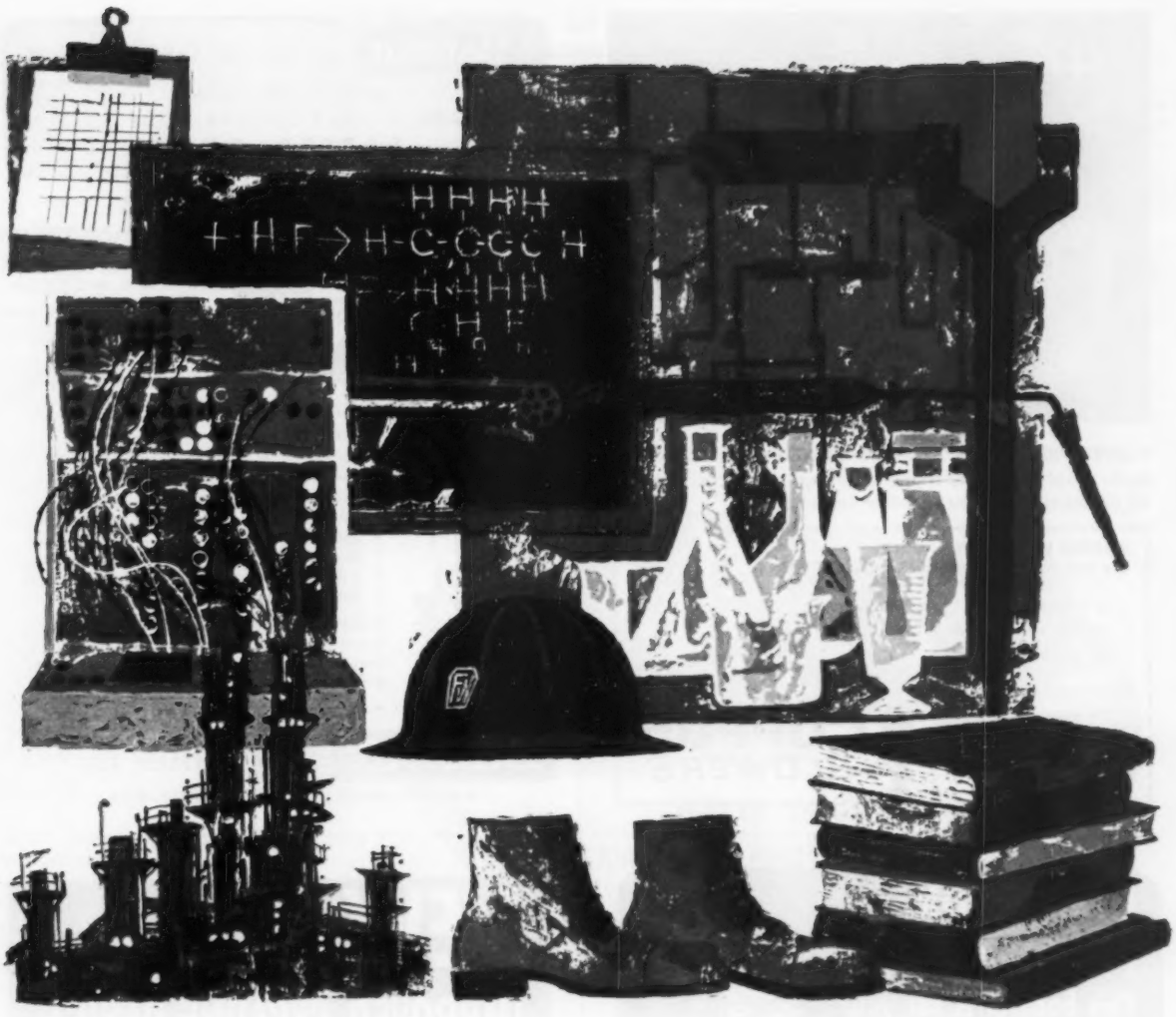
Two new products, believed to be major advances in cold-applied protective coatings, are being produced. Both are highly resistant to permeation by



chemicals. One is a heavy duty protective coating particularly suited for intermittent splash and high chemical "fallout" areas. The new polymer emulsion is called Bituplastic No. 33. Its permeability is so low that it is the first coal-tar emulsion-type coating suitable for use in intermittent immersion.

The polymer emulsion can be applied by brush, roller or spray. It is intended for use on structural steel, for deck areas and on sheet piling. Its extraordinary resistance to abrasion and high temperature tolerance (up to 400°F) extends the range of probable use.

The other new coating, Bituplastic No. 44, also has a very low permeability rating. It has been successfully used to adhere cellular glass insulating blocks to storage tanks and to underground piping,



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At Foster Wheeler you will find everything you need to make your process ideas a commercial success. There are men skilled in laboratory research and commercial evaluation to probe the practical possibilities of your ideas. To design and engineer your process plant there is a community of engineering professions—structural, heat and power, chemical, hydraulic, process . . . experts on pressure vessels and instrumentation . . . and people experienced in project management, plant construction and start-up.

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Two recent examples are plants delivered in good time and in good working order, operationally ready for quick write-off. They are a new ammonia plant producing in excess of 300 ton/day that exceeded rated capacity within 30 days of start-up; and a complete lube oil plant built in the Middle East which was in full production less than two years after award of the contract.

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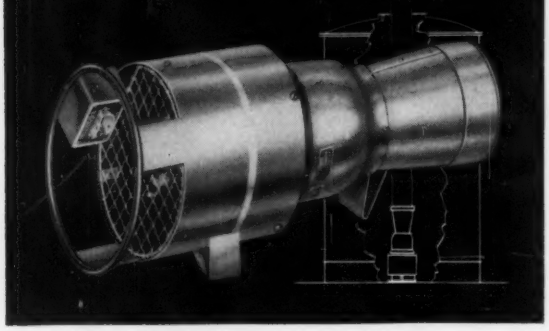
COPPUS BLUE RIBBON PRODUCTS



COPPUS "Blue Ribbon" Ventilator-Blowers are portable and easily adaptable . . . for supplying fresh air or discharging foul air or fumes. Mail coupon below for facts.

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416 Park Avenue, Worcester 10, Mass.

- ☐ in tanks, tank cars
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- ☐ for exhausting welding fumes
- ☐ on boiler repair jobs
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- ☐ to stir up stagnant air wherever men are working or material is drying

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Company .....
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COPPUS BLOWERS

Babbitt *Adjustable* **SPROCKET RIM**
with Chain Guide
CHANGES THAT DANGER ZONE TO A SAFETY ZONE

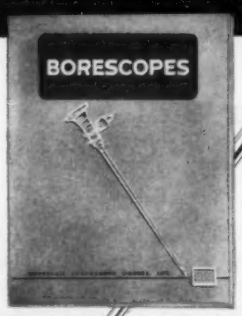
The distance between the floor of your plant and your overhead valves is a DANGER ZONE when piled up boxes or even ladders are used to reach the valves.
Turn it into a SAFETY ZONE — equip your overhead valves with Babbitt Adjustable Sprocket Rims with Chain Guides.

- They simplify pipe layout.
- They fit any size valve wheel.
- They are easy to install and operate.
- They operate any valve from the floor.
- They save time and money.
- The first cost is the only cost (no maintenance).
- They are packed completely assembled (one to a carton), with easy-to-follow instructions.
- A hot-galvanized rust proof chain is available for all sizes.

Babbitt Adjustable Sprocket Rims with Chain Guide are carried in stock by most mill supply houses. If your supplier does not carry them, contact us direct.

Babbitt STEAM SPECIALTY CO.
6 BABBITT SQUARE, NEW BEDFORD, MASS., U.S.A.

INSPECTION PROBLEMS?
This booklet is for you!



This comprehensive, elaborately illustrated booklet provides practical information on the use of the famous A. C. M. I. Borescope in various industries, for the inspection of interior areas or surfaces not otherwise visible—together with full data on the types of Borescope available, and on their care and maintenance. Have you received your copy?

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8 PELHAM PARKWAY PELHAM MANOR, N. Y.

Gentlemen: Please send me without obligation a copy of your booklet on Borescopes.

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Firm_____
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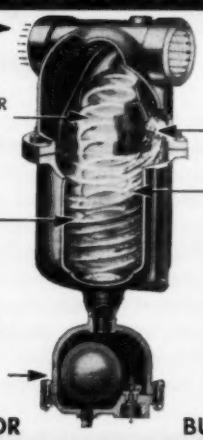
NEW T TYPE SEPARATOR
IMPROVED CYCLONE DESIGN
ASSURES MAXIMUM ENTRAINMENT SEPARATION



IN-LINE INSTALLATION
LARGE, HI LEVEL OUTLET CHAMBER NO REENTRAINMENT PROBLEM
ENTRAINMENT HUGS WALL FLOWS TO BOTTOM DRAIN
AUTOMATIC DRAINAGE WITH WRIGHT-AUSTIN FLOAT OR BUCKET TRAPS

SCREWED OR FLANGED ENDS
HI SPEED ENTRY— MAX. CENTRIFUGAL ACTION
CLEAN DESIGN PRODUCES MIN. PRESSURE LOSS
AVAILABLE IN SIZES TO 8" PRESSURES TO 1,000 P.S.I.
AVAILABLE IN SEMI OR CARBON STEEL

WRITE FOR BULLETIN 810-A

WRIGHT-AUSTIN COMPANY
3245 WIGHT STREET • DETROIT 7, MICH.

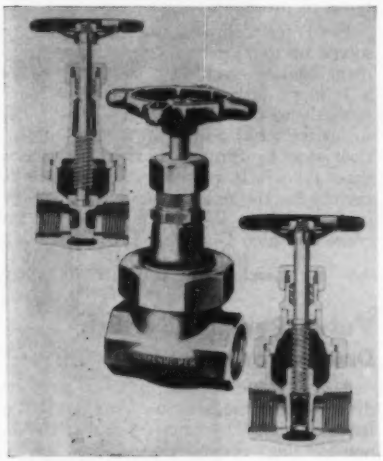
Equipment . . .

and as a general purpose insulation mortar. It is ideal as a top coating for insulation. Koppers Co., Inc.

Circle E17 green card, last page

Maintenance Costs Cut In New Bronze Gate Valve

To add an extra measure of safety for plant and personnel and to reduce valve maintenance costs, a new series of union



bonnet bronze gate valves has been announced.

The combination of three design elements—union bonnet, reinforced body, and cylindrical-body neck section—makes the new series one of the most safe and maintenance-free available to all industrial piping and valving systems.

Additional "plus" feature is the chamfered opening inside the top of the body, providing more working room for positioning the discs on the guide when assembling the valve. Long pipe threads in the valve body permit tight valve-to-pipe jointing, without risk of pipe crowding and distorting the valve discs. Lunkenheimer Co.

Circle E18 green card, last page

Olefin Plant Processes Covered In New Brochure

Olefin plants and a description of a company's olefin process are highlights of a new *Kelloggram*. A flow sequence of an olefin plant and a flow sheet design for an ethylene operation illustrate the company's approach to engineering and constructing olefin facilities. A graph showing olefin yield as a function of conversions helps illustrate a chapter on pyrolysis.

Another section of the 12-page brochure, in color, cites recent advances in olefin-plant engineering. Economic significances of olefin plant designing are also discussed. The M. W. Kellogg Co.

Circle E19 green card, last page

New Edition Of Tubing Guide Has Been Released

A revised edition of the small tubing "Selection and Application Guide" has been published.

The 12-page bulletin—designed for fast, easy selection of tubing for any given application—briefly summarizes the significant properties of 84 tubing analyses in seven groups: carbon steels, stainless steels, alloy steels, nickel and nickel alloys, copper-base alloys, glass-sealing alloys and reactive metals.

Each alloy is described in an easy-to-read tabular style which provides the AISI type number, available form (seamless or Weldrawn), characteristics, and applications. Superior Tube Co.

Circle E20 green card, last page

Computer Service Gives Complete Piping Analysis

A computer service bureau that produces a piping flexibility analysis within 48 hours is in operation. If needed, an analysis can be provided within a few hours. Here is how the service works:

1. Clients prepare a simple description of their piping system on data sheets that are sent to the bureau.
2. The bureau punches the information into IBM cards and processes it on an IBM 704 computer. This cycle normally takes 12 hours, but can be stepped up if necessary.

Reports include anchor and restraint reactions; forces, moments and stresses at all intermediate points as well as displacements and rotations. Tangents,

the KEMCO code / *THOROUGH QUALITY CONTROL INSPECTION*
SPECIFICATIONS MATCHED EXACTLY
DELIVERY WHEN PROMISED

We'd like to furnish you more information. Please write today for illustrated brochure and additional data on personnel, facilities and customers to:

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West Coast Representative:
ENGINEERED PROCESS EQUIPMENT CO.
774 E. Green • MU 1-6663 • Pasadena, Calif.

Offices in Oakland:
TEmplar 2-5391

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bends and closed loops in any combination having any orientation are permissible. Changes to a system are easily specified because coordinates are not used in the input data.

Flexibility and stress intensification factors are automatically introduced by the program. The Service Bureau (IBM Subsidiary).

Circle E21 green card, last page

Chemical Additives Solve Refinery Fouling Problems

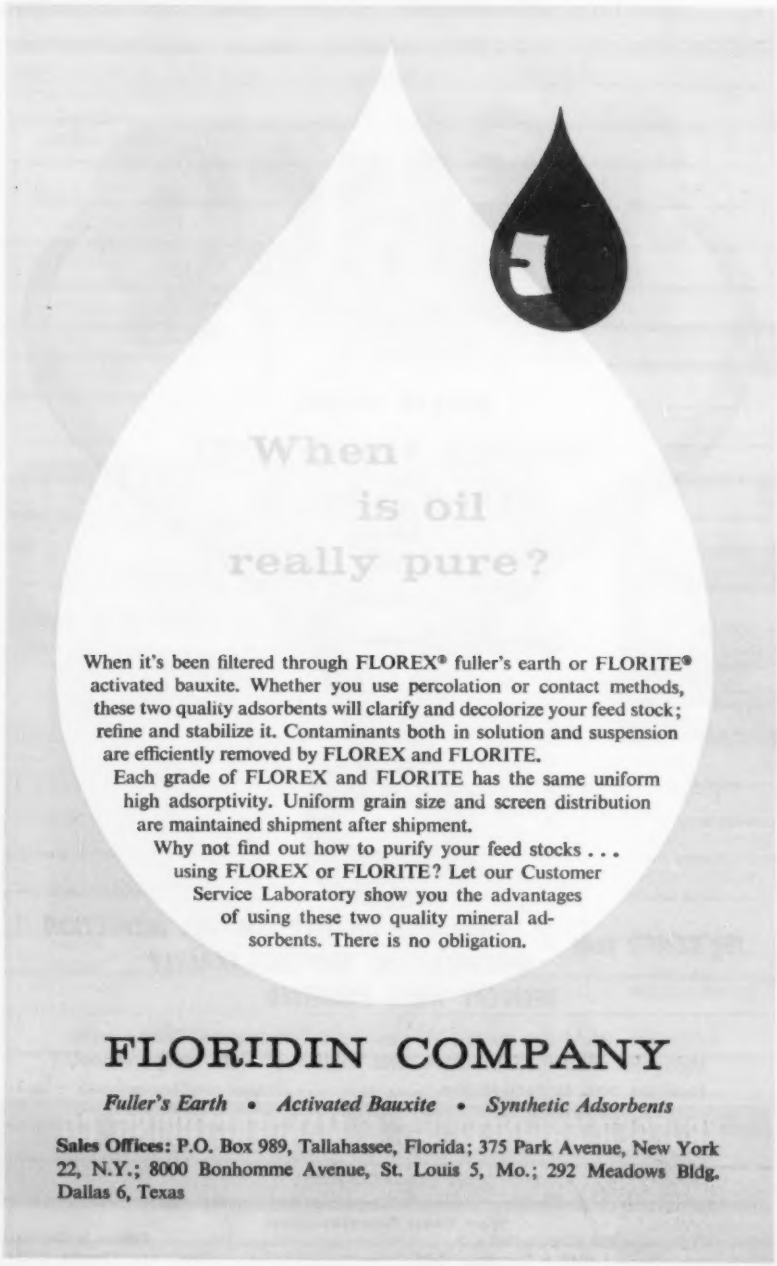
A method designed specifically to prevent organic fouling in refinery process equipment has been announced. With proper application, Nalco 262, a new chemical stabilizer-dispersant, is said to reduce or eliminate potential deposit-forming materials that foul heat exchangers, furances, reboilers and distillation columns.

The amber-colored, hydrocarbon-soluble additive is injected into naphtha and gas-oil streams ahead of the point where fouling occurs. It has been found that 262's stabilizing action minimizes polymer formation, while its dispersant action prevents sludge build-up on equipment surfaces.

In announcing the 262 anti-fouling program, the manufacturer pointed out that equipment fouling has become increasingly acute with the advent of catalytic desulfurization and reforming. Volume on catalytic desulfurization of naphtha and gas oil has been estimated at 2 million bpd. Run lengths of a few months in these units are not uncommon compared with normal turnarounds of more than six months to a year in other types of processing equipment.

Field tests showed the new additive solved up to 90 percent of refinery equipment fouling problems. In one instance a refinery faced with shutdown once monthly to clean a furnace (prior to desulfurizer), has now been without downtime due to furnace fouling for better than a year. It represented considerable savings for the refiner in downtime, labor costs and heat losses, while thruput increased. Nalco Chemical Co.

Circle E22 green card, last page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is oil
really pure?
When it's been filtered through FLOREX® fuller's earth or FLORITE® activated bauxite. Whether you use percolation or contact methods, these two quality adsorbents will clarify and decolorize your feed stock; refine and stabilize it. Contaminants both in solution and suspension are efficiently removed by FLOREX and FLORITE.
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Valve Permits Bottom Drain From Storage

A new valve that permits water to be drained from the bottom of storage tanks, features high flow capacity and packless, non-freezing construction. The double-valve design has the inner and outer valve mounted on the same stem. It is the only valve available that permits the operator to push on the handle with the inner valve closed and the outer valve open, to flush any particles that might cause leakage off the seat of the inner valve. In four sizes, the valve is available with threaded or flanged tank mounting. The Johnston & Jennings Co.

Circle E23 green card, last page

Hydrocarbon Handling Techniques In Brochure

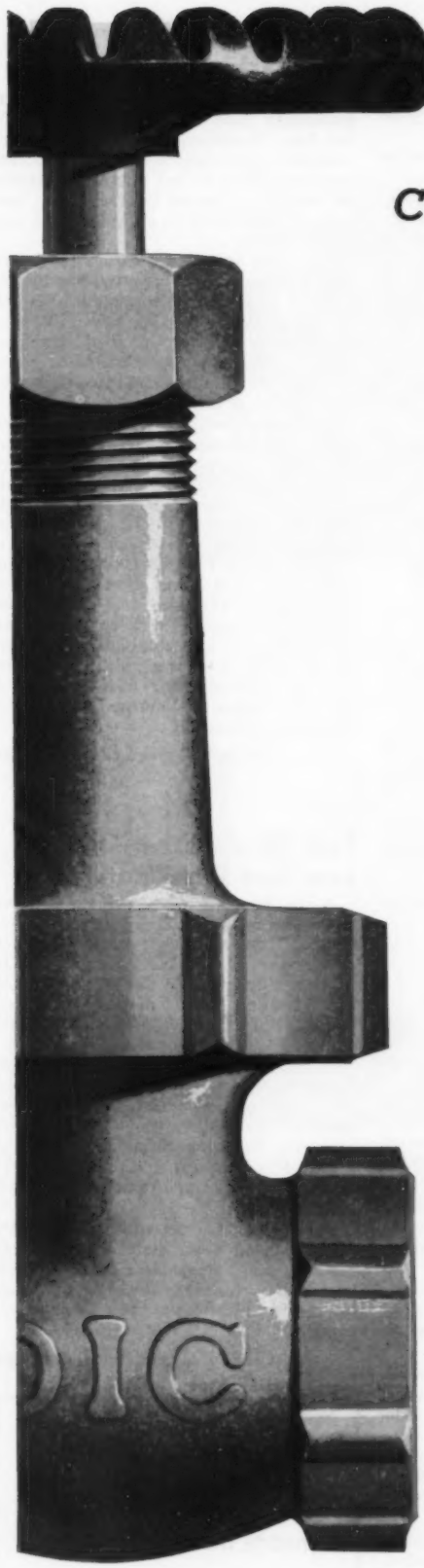
A 35-page brochure on handling techniques for C_4 hydrocarbons has just been released. It covers all of the common shipping methods and modern unloading techniques for each method. The brochure also includes the fire, explosion and toxicological hazards associated with these hydrocarbons as well as their physical properties. Petro-Tex Chemical Corp.

Circle E24 green card, last page

Top Entry Featured In Thermoplastic Ball Valve

Development of the first line of top-entry, top-adjusting thermoplastic ball valves has been announced.

The new valves are made of UPVC (unplasticized polyvinyl chloride) for operating temperatures to 150° F and "Penton" (new chlorinated polyether) for



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SERVICE to meet your valve needs is the "specialty of the house" at your nearby OIC Valve Distributor. As a first-line distributor, he gets OIC's all-out support to insure that you get the service you deserve. OIC's strategically located warehouses, and complete-line factory inventory "backstop" every OIC distributor with a multi-million dollar stock of bronze, iron, ductile iron, cast and forged steel valves. As a result of this strong distributor support, immediate delivery of the more popular items out of distributor's stock is common, and 4 to 5-day delivery out of warehouse or factory stock is routine. When quality is a problem, or delivery is urgent, phone your OIC distributor. Service is his business, and ours.

OIC VALVES | FORGED AND CAST STEEL, BRONZE, IRON AND DUCTILE IRON VALVES

THE OHIO INJECTOR COMPANY • WADSWORTH, OHIO

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For Uniform QUALITY

Specify CHICAGO-WILCOX GASKETS

RING GASKETS

For ring-type flanged joints in high-pressure lines. Made of soft iron, standard steel alloys or any non-ferrous metal to any desired cross section. **Ask for Bulletin 563.**

HEAT EXCHANGER GASKETS

Made in any size or shape needed in double-jacket type. Also cut from solid metal or sheet packing. **Ask for Bulletin 564.**

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Plain or jacketed type. Made of ingot iron, aluminum, stainless steel, copper, brass, nickel and monel in all sizes and shapes. **Ask for Bulletin 565.**

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7719 So. Avalon Ave., Chicago 19, Ill.

STORAGE TANK VENT DRIER

This inexpensive drying column will absorb all water vapor from air entering a tank. Moisture sensitive liquids may be stored without contamination by water vapor. Details on request.

W. A. Hammond Drierite Co.

120 Dayton Avenue, Xenia, Ohio

Equipment . . .

hot corrosive service to 250°F and higher. They come in ½ through 3-inch nominal pipe sizes, threaded or socket type.

Top-entry feature of the new ball valve makes it possible to perform on-the-line maintenance almost instantaneously. Quick, easy access to working parts without disconnecting any piping is achieved by simply unscrewing the valve bonnet and lifting out the molded, one piece ball-and-stem and self-lubricating "Teflon" seating inserts. An adjusting nut on the valve bonnet also enables adjustment of ball seating force from the top, eliminating the need to break or adjust connected piping in order to perform this operation. Tube Turns Plastics, Inc.

Circle E25 green card, last page

Drip-proof And Enclosed Induction Motor Brochure

A new colorful, illustrated brochure on induction motors has been released. It covers frame sizes 585 to 589 in the Crocker-Wheeler induction series, up to 400 hp in dripproof enclosures and up to 350 hp in the enclosed machines.

Large photos illustrate various construction details including stator frame and core, rotor, ventilation of dripproof motors and of the ribbed-frame, external fan-cooled enclosed motors, sleeve bearings and open-greasable ball bearing designs, and other modifications. Elliott Co.

Circle E26 green card, last page

12-Page Catalog Covers Pneumatic Instruments

Pneumatic instruments for the process industries are described in a new 12-page catalog in which pressure and temperature pilots and pneumatic transmitters are featured. Pilot specifications are listed and control actions described. Optional indicating-controller features are covered, including pneumatic set-point, control bypass and valve positioner. Pressure and temperature-transmitter specifications are also given.

Photographs highlight mechanical construction features of both types of instruments. Diagrams show case dimensions and mounting arrangements.

Catalog 515 includes detailed information on measuring elements for use with both. Pressure measuring elements include bourdon-tube, helical movement, diaphragm and bellows types. Mercury vapor and gas and organic-liquid actuated temperature measuring elements are included.

Ordering is simplified by a "Fill-in" guide which conveniently lists all needed information. U.S. Gauge Div., American Machine & Metals, Inc.

Circle E27 green card, last page

Copper And Mercury Alloy Cuts Exchanger Fouling

A radically new condenser and heat exchanger tube alloy, called Alloy 77, has been developed. It is the first commercial copper-base alloy to incorporate mercury. Alloy 77 has unusual resistance to biofouling, resists dezincification and has good resistance to other forms of corrosive attack.

The alloy was developed for condenser and heat exchanger applications where fresh or saline waters support the growth of algae. When the surface of a condenser tube becomes biofouled, the slime not only promotes corrosion of the metal but also impairs the heat transfer efficiency of the tubes.

Field and actual service tests cover prolonged exposure to clean sea water, brackish water, polluted sea water and to fresh waters containing organic materials and silt. In general, these tests showed that the water-deposited scale was thin and easily removed by mechanical cleaning procedures. Experience with the alloy indicates that a lower concentration or less frequent and shorter chlorination periods are required to keep these tubes clean. The excellent anti-biofouling qualities of Alloy 77 improve and help maintain the over-all heat transfer rate of condenser tubes for long periods of time. Bridgeport Brass Co.

Circle E28 green card, last page

Fuel Oil Additive Gives Low Cost Stabilization

A new potent low-cost fuel oil additive has been announced. Tradenamed "Polyflo 120," the additive provides effective stabilization of fuel oil at lower cost. It is especially suitable for treatment of No. 2 heating oil and diesel fuel derived from a wide range of crude stocks and can be applied to other distillates.

Treatment costs using Polyflo 120 range from one-fourth to one-half cent per barrel with recommended concentrations of five to ten pounds per 1,000 barrels. In comparison, recommended dosage for a typical additive frequently varies between 25 to 75 pounds per 1,000 barrels.

Polyflo 120 is water white. It is highly effective as a color stabilizer, sediment inhibitor and anti-emulsion agent. It can be added to distillate stocks before, during or after blending at the refinery. Universal Oil Products Co.

Circle E29 green card, last page

Use readers' service postcard, page 361, for more information on advertised products

The pump must match the application

The available range of our RPK Process Pumps offers the Oil Industry a selection that fully meets the fundamental requirement stated above.

The special characteristics of this pump are maximum reliability and economical operation at all operating points. Other features are the wide range of capacities and applications, the ease with which erection and disassembly can be carried out, and parts subject to wear renewed. The design includes a high factor of safety.

The parts particularly liable to deteriorate by wear are standardized for the widest possible range of sizes, and thus the maintenance of an adequate stock of spares is greatly facilitated.

Every type of service is catered for in respect of shaft sealing, which may be by means of the conventional packed stuffing-box or one of a great variety of mechanical seals.

KSB

Klein, Schanzlin & Becker Aktiengesellschaft, Frankenthal (Pfalz) Germany

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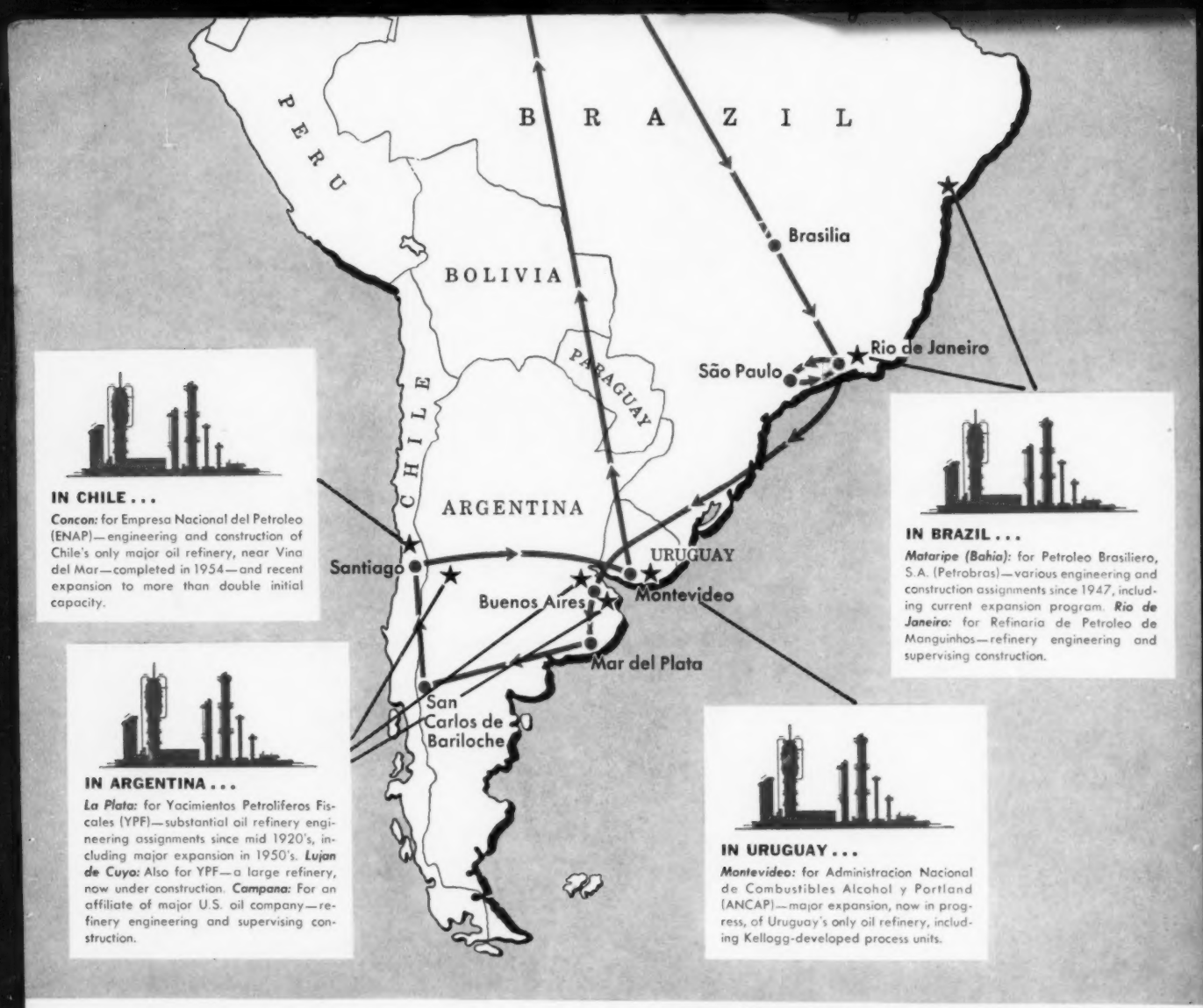

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